This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

STANFORD UNIVERSITY LIBRARIES

513

SIMON NEWCOMB.

ARTHUR AUWERS.

PUBLICATIONS

OF THE

ASTRONOMICAL SOCIETY

OF THE PACIFIC.

VOLUME XII.

1900.

SAN FRANCISCO:
PRINTED FOR THE SOCIETY
1900.

LIBRARY OF THE
LELAND STANFORD JR. UNIVERSITY.
a. 50971
MAR 26 1901

MICROFILM AVAILABLE

MICROFILM AVAILABLE

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XII. SAN FRANCISCO, CALIFORNIA, FEBRUARY 1, 1900. No. 72.

LIST OF MEMBERS
OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC.

JANUARY 1, 1900.

OFFICERS OF THE SOCIETY.

Mr. GEORGE C. PARDEE (Chronicle Building, S. F.)	*President*
Mr. JAMES E. KEELER (Lick Observatory)	*Vice-Presidents*
Mr. CHARLES BURCKHALTER (Chabot Observatory)	
Miss R. O'HALLORAN (1427 Post Street, S. F.)	
Mr. C. D. PERRINE (Lick Observatory)	*Secretary*
Mr. F R. ZIEL (301 California Street, S. F.)	*Secretary and Treasurer*

Board of Directors — Messrs. BURCKHALTER, CAMPBELL, HILL, KEELER, MOLERA, Miss O'HALLORAN, Messrs. PARDEE, PERRINE, PIERSON, VON GELDERN, ZIEL.

Finance Committee — Messrs. PIERSON, VON GELDERN, HILL.

Committee on Publication—Messrs. AITKEN, TOWNLEY, VON GELDERN.

Library Committee — Messrs. TOWNLEY, GEO. C. EDWARDS, Miss O'HALLORAN.

Committee on the Comet-Medal — Messrs. KEELER *(ex-officio)*, PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee — Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee — Mr. FRANCISCO RODRIGUEZ REY.

LIST OF MEMBERS.*

Prof. R. G. AITKEN	Lick Observatory, Mt. Hamilton, Cal.
Mr. J. H. ALBERT	Salem, Oregon.
Prof. W. STEADMAN ALDIS, *F.R.A.S.	Kidlington, near Oxford, England.
Prof. W. D. ALEXANDER	Honolulu, Hawaiian Islands.
Mr. RICHARD H. ALLEN*	Chatham, Morris Co., N. J.
Mr. CHARLES ALTSCHUL	London, Paris and American Bank, S. F., Cal.

---

* A star signifies Life Membership. Total membership, 291 (73 life members).

Hon. Henry B. Alvord*	San José, Cal.
Hon. William Alvord*	2548 Jackson St., S. F. Cal.
Mrs. William Alvord*	2548 Jackson St., S. F., Cal.
Mr. F. S. Archenhold	Treptow Sternwarte, bei Berlin, Germany.
Astronomical and Physical Observatory	Taschkent, Turkestan, Russia.
Mr. J. J. Aubertin,* F.R.A.S.	33 Duke St., St. James, S. W., London, England.
Mr. Allen H. Babcock	1216 Webster St., Oakland, Cal.
Mr. J. Bassett	82 High St., Stoke Newington N. London, England.
Mr. John Bermingham*	330 Market St., S. F., Cal.
Mrs. Bevan	46 Queen's Gate Terrace, S.W., London, England.
Prof. Albert S. Bickmore	American Museum of Natural History, Central Park, New York, N. Y.
Mr. Wilbert M. Birge	Davenport, Nebraska.
Mr. R. L. Bischoffsheim,* F.R.A.S.	3 Rue Taitbout, Paris, France.
Mr. Charles R. Bishop	Occidental Hotel, S. F., Cal.
Mr. Thomas B. Bishop*	532 Market St., S. F., Cal.
Mr. Anson Stiles Blake	Berkeley, Cal.
Mr. Henry Lord Boulton, Jr.,* F.R.A.S.	Carácas, Venezuela, or Box 2015, New York, N. Y.
Colonel E. D. Boyle	Gold Hill, Storey Co., Nev.
Prof. F. P. Brackett	Pomona College, Claremont, Cal.
Mr. Frederick E. Brasch	College Park, San José, Cal.
Mr. J. A. Brashear, F.R.A.S.	Allegheny City, Pa.
Rev. M. S. Brennan	St. Lawrence's Church, St. Louis, Mo.
Mr. Leo Brenner	Manora - Sternwarte, Lussinpiccolo, Istrien.
Mr. Edward M. Brewer	27 Kilby St., Boston, Mass.
Mr. Joseph Brooks, F.R.A.S., F.R.G.S.	Hope Bank, Nelson St., Woollahra, via Sydney, New South Wales.
Miss C. W. Bruce*	810 5th Ave., New York, N. Y.
Mr. Charles Burckhalter, F.R.A.S.	Chabot Observatory, Oakland, Cal.
Miss Mary E. Byrd	The Observatory, Smith College, Northampton, Mass.
Dr. J. Callandreau*	114 Montgomery St., S. F., Cal.
Prof. W. W. Campbell	Lick Observatory, Mt. Hamilton, Cal.
Mr. Andrew Carnegie*	5 West 51st St., New York, N.Y.
Mr. J. C. Cebrian*	Pine and Octavia Sts., S. F., Cal.
Dr. V. Cerulli	Observatorio Privato, Teramo, Italy.
Mr. B. G. Clapp	The Academy, Fulton, N. Y.
Dr. E. S. Clark	16 Geary St., S. F., Cal.

Miss Isabella D. Clark . . . . San José, Cal.
Mr. Mateo Clark* . . . . 9 New Broad St., E. C., London, England.
Mr. Ernest A. Cleveland . . . . . Vancouver B. C.
Mr. E. F. Coddington . . . . Lick Observatory, Mt. Hamilton, Cal.
Mr. A. L. Colton* . . . . Box 1314, Ann Arbor, Mich.
Major S. Comfort . . . . Standard Oil Co. of New York, Bombay, India.
Mr. J. Costa . . . . 114 Montgomery St., S. F., Cal.
Mr. Henry Cowell* . . . . 413 Hyde St. S. F., Cal.
Mr. George Crocker* . . . . Mills Building, New York, N. Y.
Mr. Henry J. Crocker . . . . 182 Crocker Bldg., S. F., Cal.
Mr. William H. Crocker* . . . . . Crocker-Woolworth National Bank, S. F., Cal.
Hon. Edward Crossley,* F.R.A.S. . Bermerside Observatory, Halifax, England.
Miss S. J. Cunningham . . . . Swarthmore College, Delaware Co., Pa.
Prof. H. D. Curtis . . . . University of the Pacific, College Park, Cal.
Mr. Chas. S. Cushing . . . . 920 Linden St., Oakland, Cal.
Mr. J. Ewen Davidson* . . . . . . Care of W. Wesley & Son, 25 Essex St., Strand, London, England.
Mr. Joseph E. Davis . . . . 154 Beacon St., Boston, Mass.
Mr. W. A. Dawson . . . . Guthrie, Oklahoma Ter.
Mrs. John H. Devereux . . . . . . 882 Euclid Ave., Cleveland Ohio.
Mr. W. H. Devine* . . . . Nagasaki, Japan.
Miss Grace H. Dodge . . . . 262 Madison Avenue, New York, N. Y.
Mr. John Dolbeer . . . . 10 California St., S. F., Cal.
Mr. Cecil Goodrich Dolmage . . . LL.D., D.C.L., F.R.A.S. 22 Upper Merrion St., Dublin, Ireland.
Mr. J. A. Donohoe . . . . Vice Prest. Donohoe-Kelly Banking Co., S.F., Cal.
Mr. W. E. Downs . . . . Sutter Creek, Amador Co., Cal.
Mrs. Anna Palmer Draper* . . . . 271 Madison Ave., New York, N. Y.
Rev. W. Arthur Duckworth, J. P. . Orchardleigh, Frome, Somerset, England
Mr. Francis G. Du Pont . . . . Wilmington, Del.
Mr. H. Dutard* . . . . 2616 Buchanan St., S. F., Cal.
Mr. Earnest I. Dyer . . . . American Trading Co., Yokohama, Japan.
Miss S. J. Eastman . . . . Ogontz School, Pa.
Prof. Geo. C. Edwards . . . . Berkeley, Cal.
Mr. W. Edwards . . . . 1519 Eddy St., S. F., Cal.
Capt. Oliver Eldridge . . . . 615 Sutter St., S. F., Cal.
Mr. John Everding, Jr. . . . . 48 Clay St., S. F., Cal.
Hon. Robert Isaac Finnemore,* F.R.A.S. Puisne Judge, Supreme Court, Pietermaritzburg, Natal, South Africa.

Mr. J. H. Firehammer	1590 Pacific Ave., Alameda, Cal.
Mr. S. Wilson Fisher	1502 Pine St., Philadelphia, Pa.
Mr. Andrew B. Forbes*	401 California St., S. F., Cal.
Mr. George Stuart Forbes	Care King, King & Co., East India Agents, Bombay, India.
Mr. Arthur W. Foster*	322 Pine St., S. F., Cal.
Mr. Fred R. French	Room 3, City Hall, Brockton, Mass.
Mr. H. C. Frick*	42 5th Ave., Pittsburgh, Pa.
Prof. Chas. W. Friend	Observatory, Carson, Nev.
Mr. Robert D. Fry*	1812 Jackson St., S. F., Cal.
Mr. Walter F. Gale, F.R.A.S.	Paddington, Sydney, N. S. W.
Mr. Jos. F. Gassmann	141 Fremont St., S. F., Cal.
Miss Susan Gearon	St. Margaret's, Barrowgate Road, Chiswick, England.
Mr. Otto von Geldern	Room 56, 819 Market St., S. F., Cal.
Dr. David Gill, C.B., F.R.A.S.	Royal Astronomer, Cape of Good Hope, Africa.
Mr. George Gleason, J.P.	South Pasadena, Los Angeles Co., Cal.
Mr. Adam Grant*	N. E. cor Bush and Sansome Sts., S. F., Cal.
Mr. Joseph D. Grant*	N. E. cor. Bush and Sansome Sts., S. F., Cal.
Mr. Andrew Greig*	3 Duntrune Terrace, Broughty Ferry, Dundee, Scotland.
Mr. C. P. Grimwood	214 Pine St., S. F., Cal.
Mr. J. O'B. Gunn	Box 2128, S. F., Cal.
Mr. David E. Hadden	Alta, Iowa.
Mr. C. F. Harms	140 Broad St., New York, N.Y.
Mr. Jackson Hatch	Porter Building, San José, Cal.
Mr. Everett Hayden	Washington, D. C.
Mrs. Phebe Hearst	Room 33, 9th floor, Mills Building, S. F., Cal.
Mr. Andrew P. Henkel	317 Locust St., Walnut Hills, Cincinnati, Ohio.
Mr. David Hewes	Occidental Hotel, S. F., Cal.
Prof. Alfred Higbie	S. W. cor. Pierce and Pine Sts., S. F., Cal.
Mr. Chas. B. Hill	212 Pine St., S. F., Cal.
Mr. Horace L. Hill*	124 Sansome St., S, F., Cal.
Miss Adelaide M. Hobe	604 Capp St., S. F., Cal.
Mr. Samuel V. Hoffman,* F.R.A.S.	91 Madison Ave., Morristown, N. J.
Dr. Edward S. Holden* Foreign Assoc. R.A.S.	4 East 43d St., New York, N. Y.
Hon. James F. Houghton	California Safe Deposit Building, S. F., Cal.
Hon. C. Webb Howard*	Pacific-Union Club, S. F., Cal.
Mr. Wm. Howat*	358 William St., Melbourne, Victoria.

Prof. W. J. HUSSEY	Lick Observatory, Mt. Hamilton, Cal.
Mrs. M. H. HUTTON	26 Union St., New Brunswick, New Jersey.
IMPERIAL OBSERVATORY	University of St. Petersburg, Russia.
Mr. FRANK JAYNES	W. U. Telegraph Co., S. F., Cal.
Mr. NELS JOHNSON	Manistee, Mich.
Prof. JAMES E. KEELER, F.R.A.S.	Director Lick Observatory, Mt. Hamilton, Cal.
Mr. CHARLES C. KEENEY*	2220 Clay St., S. F., Cal.
Dr. F. P. VON KELLER	Ardmore, Indian Ter.
Mr. JAMES R. KELLY	309 Leavenworth St., S. F.
Mr. JOHN W. KENDRICK	Gen. Mgr. N.P.R.R., 230 Oak Grove St., Minneapolis, Minn.
Mr. A. E. KENNELLY,* F.R.A.S.	Crozer Building, Philadelphia, Pa.
Mr. DONALD KING	8 Church Lane, Hornsey, London, England.
Mr. SYDNEY T. KLEIN,* F.R.A.S.	Observatory, Great Stanmore, Middlesex, England.
Dr. DOROTHEA KLUMPKE	National Observatory, Paris, France.
Mr. TORVALD KÖHL*	Odder, Denmark.
Mr. FR. KOEPPEN	Stueler Strasse 2, Berlin, W. Germany.
Prof. H. KREUTZ	Kiel, Germany.
Mr. C. F. DE LANDERO*	P. O. Box 1, Pachuca, State Hidalgo, Mexico.
Hon. MANUEL FERNANDEZ LEAL	Calle de Cordovanes No. 3, City of Mexico, Mexico.
Prof. F. P. LEAVENWORTH	University of Minnesota, Minneapolis, Minn.
Prof. JOSEPH LE CONTE, LL.D.	Berkeley, Cal.
Rev. EDMUND LEDGER, M.A., F.R.A.S.	Protea, Doods Road, Reigate, England.
Mr. CLARENCE MACKENZIE LEWIS*	Engineering Department Baltimore & Ohio Southwestern Railway, Cincinnati, Ohio.
CALIFORNIA STATE LIBRARY	Sacramento, Cal.
LIBRARY OF THE CHABOT OBSERVATORY	Oakland, Cal.
THE CITY LIBRARY	Lowell, Mass.
FREE PUBLIC LIBRARY	Newark, New Jersey.
FREE PUBLIC LIBRARY	Worcester, Mass.
THE JOHN CRERAR LIBRARY	Chicago, Ill.
LIBRARY OF THE LELAND STANFORD JR. UNIVERSITY	Stanford University, Cal.
LIBRARY OF THE LICK OBSERVATORY	Mount Hamilton. Cal.
LIBRARY OF THE MECHANICS' INSTITUTE	31 Post St., S. F., Cal.
LIBRARY OF THE MINNEAPOLIS ATHENÆUM	Minneapolis, Minn.
NEW YORK PUBLIC LIBRARY	40 Lafayette Place, New York, N. Y.

Library of Princeton University	Princeton, New Jersey.
The Public Library	Boston, Mass.
Library of St. Gertrude's Academy	Rio Vista, Cal.
Library of St. Ignatius College	San Francisco, Cal.
Library of the University of California	Berkeley, Cal.
Library of the University of Illinois	Champaign, Illinois.
Library of the University of Indiana	Bloomington, Indiana.
Library of the University of Pennsylvania	Philadelphia, Pa.
Library of Yale University	New Haven, Conn.
Mr. Adolph Lietz	422 Sacramento St., S. F.
Mr. John D. Locke	Haverhill, New Hampshire.
Mr. Henry B. Loomis*	Seattle, Washington.
Prof. Henry C. Lord	Director of the McMillin Observatory, Ohio State University, Columbus, Ohio.
Mr. W. H. Lowden	314 California St., S. F., Cal.
Mr. Edward G. Lukens	200 Market St., S. F., Cal.
Mr. Geo. Russell Lukens	1350 Madison St., Oakland, Cal.
Mr. Frank E. Lunt	Care R. G. Lunt, Los Angeles, Cal.
Mr. James D. Maddrill	830 Eighteenth St., Oakland, Cal.
Miss Agnes M. Manning	1215 Sutter St., S. F., Cal.
Mr. Marsden Manson, C.E., Ph.D.	Bureau of Highways, Sacramento, Cal.
Mr. F. Martens	College Point, Queen's Co., New York.
Mr. Camilo Martin	Room 4, 632 Market St., S. F., Cal.
Hon. E. S. Martin	P. O. Box 75, Wilmington, N.C.
Mr. John Martin	Puruatanga, Martinborough, Wairarapa, Wellington, New Zealand.
Prof. A. M. Mattoon	Scott Observatory, Parkville, Missouri.
Mr. W. H. Maw,* F.R.A.S.	18 Addison Road, Kensington, London, England.
Mr. Frank McClean,* M.A., F.R.A.S.	Rusthall House, Tunbridge Wells, England.
Mr. F. H. McConnell	14 Post St., S. F., Cal.
Mr. John McDonough	193 28th St., Brooklyn, N. Y.
Prof. T. E. McKinney	Marietta College, Marietta, Ohio.
Prof. Malcolm McNeill	Lake Forest, Ill.
Hon. Albert Miller*	532 California St., S. F., Cal.
Prof. E. Miller	University of Kansas, Lawrence, Kansas.
Hon. D. O. Mills*	15 Broad St.. New York, N. Y.
Dr. Lewis F. Mizzi	Constantinople, Turkey.
Mr. James K. Moffitt	First National Bank, S.F., Cal.

Mr. E. J. Molera,* C.E.	606 Clay St., S. F., Cal.
Mr. W. H. S. Monck, F.R.A.S.	16 Earlsfort Terrace, Dublin, Ireland.
Mr. Beverly K. Moore	56 Bedford St., Boston, Mass.
Mr. Fremont Morse, U.S.C. & G. Survey.	P. O. Box 2512, S. F., Cal.
Mr. William S. Moses	Turk St., bet. Masonic and Parker Aves., S. F., Cal.
Mr. Mich. Mullany	N. W. cor. Washington and Scott Sts., S. F., Cal.
Mr. C. A. Murdock	2710 Scott St., S. F., Cal.
Hon. B. D. Murphy*	San José, Cal.
Mr. Charles Nelson	6 California St., S. F., Cal.
Mr. H. F. Newall,* F.R.A.S.	Observatory of the University, Cambridge, England.
Mr. G. W. Nicolls, F.R.A.S.	Caixa 776, Rio de Janeiro, Brazil.
Mr. P. Noordhoff	Groeningen, Holland.
Mr. Charles Nordhoff	Coronado, Cal.
Miss Rose O'Halloran	1427 Post St., S. F., Cal.
Miss M. A. Orr	Highbridge, Frimley, Surrey, England.
Mr. Harold K. Palmer	Lick Observatory, Mt. Hamilton, Cal.
Mr. T. S. Palmer	Department of Agriculture, Washington, D. C.
Dr. George C. Pardee	Chronicle Building, S. F., Cal.
Miss Clara A. Pease	High School, Hartford, Conn.
Mr. George W. Percy	318 Boulevard Terrace, Oakland, Cal.
Hon. Geo. C. Perkins*	Oakland, Cal.
Prof. H. B. Perkins	Box 240, Pasadena, Cal.
Mr. A. Perrenod	Saint-Pierre, Martinique.
Mr. C. D. Perrine	Ass't Astronomer, Lick Observatory. Mt. Hamilton, Cal.
Mr. Henry Phipps, Jr.*	Carnegie, Phipps & Co., Pittsburgh, Pa.
Mr. John Jay Pierrepont	1 Pierrepont Place, Brooklyn, Kings Co., N. Y.
Mr. Lawrence H. Pierson	Pacific Pine Co., S. F., Cal.
Prof. Willett C. Pierson	214 West 78th St., New York, N. Y.
Hon. Wm. M. Pierson, F.R.A.S.	4th floor, Mills Building, S. F., Cal.
Mr. Ruthven W. Pike*	166 La Salle St., Chicago, Ill.
Miss Juliet Porter*	37 Deane St., Worcester, Mass.
Mr. Charles A. Post	Bayport, Long Island, N. Y.
Mr. Walter A Post	Newport News, Virginia.
Mr. Wm. Appleton Potter	39 W. 27th St., New York, N.Y.
Mr. Enos Putman*	Grand Rapids, Michigan.
Mr. J. C. Rabe	P. O. Box 301, Mare Island, Vallejo, Cal.
Mr. Albert Raymond	202 Sansome St., S. F., Cal.

Mr. M. Reiman	4325 Drexel Boulevard, Chicago, Ill.
Mr. Ernest K. Roden	International Correspondence Schools, Scranton, Pa.
Mr. Francisco Rodriguez Rey	National Observatory, Tacubaya, Mexico.
Rev. J. L. Ricard, s.j.	Santa Clara, Cal.
Mrs. William Gorham Rice	135 Washington Ave., Albany, N. Y.
Mr. Daniel S. Richardson	Cor. Lincoln and Summit Sts., East Oakland, Cal.
Mrs. Arthur Rodgers*	Leavenworth and Vallejo Sts., S. F., Cal.
Dr. W. H. Rollins	250 Marlboro St., Boston, Mass.
The Earl of Rosse, F. R. A. S.	Birr Castle, Parsonstown, Ireland.
Baron Albert von Rothschild*	Vienna, Austria.
Mr. John R. Ruckstell	182 Crocker Bld'g, S. F., Cal.
Mr. Alexander Rydzewski	Officer St., House 13, Lodging 26, St. Petersburg, Russia.
Mr. Joseph C. Sala	429 Montgomery St., S. F., Cal.
Mr. John W. Salsbury	Port Tampa City, Florida.
Prof. J. M. Schaeberle*	Lick Observatory, Mt. Hamilton, Cal.
Mr. Jacob H. Schiff*	932 Fifth Ave., New York, N.Y.
Mr. Herman Schussler	Pacific-Union Club, S. F., Cal.
Mr. Henry T. Scott	Box 2128, S. F., Cal.
Mr. James L. Scott, F. R. A. S.	Care Scott, Harding & Co., Shanghai, China.
Rev. George M. Searle	Catholic University of America, Brookland, D. C.
Mr. Frederick H. Seares	Berkeley, Cal.
Dr. J. M. Selfridge	Box 37, Oakland, Cal.
Mr. Garrett P. Serviss	8 Middagh St., Brooklyn, N.Y.
Dr. T. Steele Sheldon, F. R. A. S.	Parkside, Macclesfield, England.
Dr. G. E. Shuey	651 E. Fourteenth St., East Oakland, Cal.
Mr. Francis Sinclair*	1305 Oxford St., North Berkeley, Cal.
Mr. Chas. S. Smith*	25 W. 47th St., New York, N.Y.
Mr. Sommers N. Smith	The Neafie & Levy Ship and Engine Building Co., Philadelphia, Pa.
Mr. C. A. Spreckels*	San Mateo, Cal.
Mrs. C. A. Spreckels*	San Mateo, Cal.
Mr. Rudolph Spreckels	2000 Gough St., S. F., Cal.
Miss Gertrude Stanford	1218 Oak St., Oakland, Cal.
Mr. Thos. W. Stanford*	142 Russell St., Melbourne, Victoria.
Mr. John W. Stetson	906 Broadway, Oakland, Cal.
Mr. Robert Stevenson	P. O. Box 2214, S. F., Cal.
Mr. H. F. Stivers	Rosewood, Tehama Co., Cal.

Mr. Chauncey M. St. John	U. S. Custom House, S. F., Cal.
Mr. Julius Stone*	Care of The Ohio Central Fuel Co., Columbus, Ohio.
Prof. W. H. von Streeruwitz	P. O. Box 465, Austin, Texas.
Prof. I. Stringham, Ph. D.	Berkeley, Cal.
Mr. Duane Studley	Wabash College, Crawfordsville, Indiana.
Mr. Daniel Suter	317 Bush St., S. F., Cal.
Mr. C. F. A. Talbot	204 California St., S. F., Cal.
Mrs. Louis Taussig	2127 California St., S. F., Cal.
Mr. George Taylor	Walnut St., Brookline, Mass.
Dr. Jesús Muños Tébar	Carácas, Venezuela, S. A.
Mr. John Tebbutt, F. R. A. S.	Observatory, Windsor, New South Wales.
Dr. A. Blair Thaw	Montecito, Santa Barbara Co., Cal.
Dr. John M. Thome*	National Observatory, Cordoba, Argentine Republic.
Dr. S. D. Townley	2023 Bancroft Way, Berkeley, Cal.
Prof. R. H. Tucker, Jr.	Lick Observatory, Mt. Hamilton, Cal.
Mr. Henry J. Turner*	Woodville, Rappahannock Co., Virginia.
Mr. Felipe Valle	Director National Observatory, Tacubaya, Mexico.
Mr. Edward H. Van Ingen	9 East 71st St., New York, N. Y.
Mr. Alfred de Vervins	3923 Delmar Boulevard, St. Louis, Mo.
Mr. J. W. Ward	271 Bourke St., Sydney, New South Wales.
Mr. W. R. Warner	Care of Warner & Swasey, East Prospect St., Cleveland, Ohio.
Dr. W. Seward Webb	Grand Central Station, New York, N. Y.
Mrs. W. Seward Webb	680 Fifth Avenue, New York, N. Y.
Prof. Dr. L. Weinek	Imperial Observatory, Prague, Austro-Hungary.
Mr. Chas. J. Welch	The Royalton, 44 W. 44th St., New York, N. Y.
Dr. Andrew D. White*	Ithaca, N. Y.
Mr. E. J. White, F. R. A. S.	Observatory, Melbourne, Victoria.
Mr. A. Stanley Williams, F. R. A. S.	20 Hove Park Villas, Hove, Sussex, England.
Mrs. Mary H. Willmarth*	222 Michigan Ave., Chicago, Ill.
Mr. Russell J. Wilson*	2027 California St., S. F., Cal.
Colonel B. Witkovsky*	St. Petersburg, W. O. 9th line, 44, Russia.
Mr. William Yates	Box 283, Station C, Los Angeles, Cal.

Mr. FREDERICK W. ZEILE* . . . . . . Room 26, 5th floor, Mills Building, S. F., Cal.
Prof. C. V. ZENGER, F. R. A. S. . . . . . . Smichow, Prague, Bohemia.
Mr. F. R. ZIEL . . . . 301 California St., S. F., Cal.

LIST OF CORRESPONDING INSTITUTIONS.

Albany, New York, Dudley Observatory.
Allegheny, Pennsylvania, Allegheny Observatory.
Armagh, Ireland, Armagh Observatory.
Berlin, Germany, Königl-Astronomisches Rechen Institut.
Berlin, Germany, Royal Observatory.
Cambridge, England, University Observatory.
Cambridge, Massachusetts, Harvard College Observatory.
Cape Town, Africa, Royal Observatory.
Christiania, Norway, University Observatory.
Cincinnati, Ohio, University Observatory.
Cordoba, Argentine Republic, National Observatory.
Dorpat, Russia, University Observatory.
Dublin, Ireland, Dunsink Observatory.
Dublin, Ireland, Royal Dublin Society.
Edinburgh, Scotland, Royal Observatory.
Geneva, Switzerland, Observatory.
Glasgow, Scotland, University Observatory.
Gotha, Germany, Ducal Observatory.
Goettingen, Germany, Royal Observatory.
Greenwich, England, Royal Observatory.
Hamburg, Germany, Hamburger Sternwarte.
Helsingfors, Russia, University Observatory.
Kasan, Russia, University Astronomical Observatory.
Kiel, Germany, University Observatory.
Kodaikanal, Palani Hills, South India, Observatory.
Koenigsberg, Germany, University Observatory.
La Plata, Argentine Republic, Observatory.
Leipzig, Germany, University Observatory.
Leyden, Holland, University Observatory.
Lisbon (Tapada), Portugal, Real Observatorio.
London, England, 26 Martin's Lane, British Astronomical Association.
London, England, British Museum.
London, England, Royal Astronomical Society.
London, England, 3 Verulam Bldgs., Gray's Inn, The Nautical Almanac.
Lund, Sweden, University Observatory.
Madison, Wisconsin, Washburn Observatory.
Madrid, Spain, Royal Observatory.
Marseilles, France, Observatory.
Melbourne, Victoria, Observatory.
Mexico, Mexico, Sociedad Cientifica "Antonio Alzate."
Milan, Italy, Royal Observatory.
Moscow, Russia, University Observatory.

Munich, Germany, Royal Observatory.
Naples, Italy, Royal Observatory.
New Haven, Connecticut, Yale University Observatory.
New York, New York, American Mathematical Society.
New York, New York, Columbia University Observatory.
Nice, France, Observatory.
Northfield, Minnesota, Carleton College Observatory.
Oxford, England, Radcliffe Observatory.
Oxford, England, University Observatory.
Paris, France, Bureau of Longitudes.
Paris, France, National Observatory.
Paris, France, Société Astronomique de France.
Philadelphia, Pa., 105 South Fifth St., American Philosophical Society.
Potsdam, Germany, Astrophysical Observatory.
Prague, Austro-Hungary, University Observatory.
Pulkowa, Russia, Imperial Observatory.
Rio de Janeiro, Brazil, Observatory.
Rome, Italy, Observatory of the Roman College.
Rome, Italy, Italian Spectroscopic Society.
Rome, Italy, Specula Vaticana.
San Francisco, California, California Academy of Sciences.
San Francisco, California, Technical Society of the Pacific Coast.
Stockholm, Sweden, University Observatory.
Strassburg, Germany, University Observatory.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, National Observatory.
Tokio, Japan, University Observatory.
Toronto, Canada, Astronomical and Physical Society of Toronto.
Toulouse, France, Observatory.
Turin, Italy, Observatory.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, Imperial Observatory.
Vienna (Ottakring), Austria, Von Kuffner's Observatory.
Washington, District of Columbia, Library of Congress.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
William's Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, William's Bay Wisconsin.
Sirius, Cologne, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications* A. S. P., vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San José, California.
The Overland Monthly, San Francisco, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

NOTES ON THE ZODIACAL LIGHT:

BEING A SUMMARY OF OBSERVATIONS MADE AT SEA SINCE 1889.

By Francis J. Bayldon, R. N. R.

During the last ten years I have paid great attention to the Zodiacal Light, whilst engaged in a nautical career, in all latitudes from 55° N. to 55° S. Having lately found that its appearance causes great interest amongst many people who have less favorable opportunities for observing it, the following brief summary of my observations may prove of interest,— though scientific accuracy is not pretended, owing to my rough, primitive modes of observations, my attention to the Light being chiefly given to while away otherwise tedious watches on deck. And no undue importance must be attached to these notes; for they are simply the results of one individual's observations, totally uncorroborated by reference to observations by others.

The actual observations given have all been made during the past twelve months, in the Pacific Ocean, whilst on board the Canadian-Australian R. M. S. *Aorangi*, trading between Sydney, N. S. W., and Vancouver, and are chosen out of scores of observations, as being of more especial interest.

As the result of my observations, it seems to me —

I. That when favorably situated, as in tropical regions, an observer may see the eastern and western cones every morning and evening, provided the sky is clear and the Moon is in her first or last quarter.

II. That on every very clear moonless night the Light is visible as a band, reaching across the entire sky throughout the whole night.

III. That frequently when the night is not clear enough for this entire band to be seen, portions of both eastern and western branches may be observed at midnight.

IV. That that part of the band situated in direct opposition to the Sun is generally (especially near the solstices) brighter than the surrounding portions. This brighter portion, elliptical in shape and about 15° long, is known as the *Gegenschein*, and appears to change its position slightly, from 2° or 3° east to 2° or 3° west of the anti-solar spot.

V. That the Zodiacal Light forms an unbroken band uniform in breadth, around the Earth. This uniform breadth being, approximately, 29°. (See pages 23–24 of this article.)

VI. That this band is inclined about 4° to the plane of the Ecliptic, its line of central axis (approximately) crossing the Ecliptic in R. A. 0^h, reaching its most northerly Declination of 27½° in R. A. 6^h; again crossing the Ecliptic in R. A. 12^h, reaching its most southerly Declination of 27½° in R. A. 18^h; again crossing the Ecliptic in R. A. 0^h.

VII. That as an observer moves to the northward, this line of central axis appears displaced to the northward; and as he moves to the southward it appears displaced to the southward, the displacement being 1° for about 19° change in latitude. This displacement seems to be greatest at small elongations from the Sun, as at the base of the cones, and seems to decrease as the elongation increases, towards the apices of the cones, and opposition. Besides this displacement, there is also another, evidently due to the refractive and absorptive properties of the atmosphere, whereby the base and lower portions of the cones are thrown still farther to the northward in north latitudes, and to the southward in south latitudes.

VIII. That there are probably slight seasonal changes in the angle which the band makes with the Ecliptic; but owing to my ever-moving, seafaring life, all such changes I have to associate with my change in latitude, especially as I never record observations ashore, those obtainable in the clearer air at sea appearing to me to be so much more reliable and better.

IX. That the apparent eastern and western cones (or spindles) are chiefly formed by atmospheric effects on the band lying immediately above the horizon, and partly by the increasing extent of circles of altitude from the zenith downwards, but that really the band is uniformly about 22° broad from horizon to zenith. These cones are particularly exaggerated in extra-tropical regions, in the tropics being hardly noticeable.

X. But that the Light is considerably brighter to an elongation of about 105° on either side of the Sun, and under favorable conditions the apices of eastern and western cones always appear to be situated at this elongation, though if the night is unfavorable they are, of course, not seen to this extent.

XI. That beyond these cones the Light can still be traced, very faint, with varying breadth, according to the clearness of the atmosphere, from 5° broad to an average breadth of 12°, to an extreme breadth of 22°, which is seldom seen, lying beyond the zenith right down to the eastern horizon at P. M., and to the western horizon at A. M. Whereas the cones rapidly taper from an apparent breadth of, say 30°, at the horizon to 10° at their apices, beyond them the band tapers only 2° or 3° in its path across the entire sky; and as the western cone sets and is followed by the band, so the band assumes a cone shape (very faint in intensity); or over the eastern horizon the light appears cone-shaped, but as it rises to the zenith it becomes of a uniform breadth.

XII. That the appearance of the Light is that of a soft white luminosity, and although slight tinges of color are occasionally noticeable, these are entirely due to atmospheric conditions. In brightness the Light, at elongation less than 105° from the Sun, frequently exceeds the brightness of the Galaxy, though at greater elongations it seldom approaches it. Occasionally I have seen the cones so bright that only stars of the second magnitude were discernible in them, but as a rule those of the third magnitude are visible. The connecting band between the cones is very faint indeed, though at times I have traced it across the sky about as bright as the Magellanic clouds. Both in the cones and the connecting band the Light appears brighter and more concentrated towards the line of central axis. So faint is the connecting band that frequently the brighter Gegenschein can be seen, on moderately clear nights, as a separate luminosity, no sign whatever of the band being visible.

XIII. That the Moon adds sufficiently to the Zodiacal Light to make it visible during her first and last quarters; but that from her first to last quarters her light totally absorbs its light, until she is below the horizon.

XIV. That the very faintest cirrus haze is most annoying and aggravating to observers of the Zodiacal Light, as it causes its boundaries to be apparently continually changing, and also its brightness to be constantly waxing and waning, whilst the presence of the haze itself would otherwise be hardly discernible in the sky.

XV. That Honolulu is most favorably situated, as regards latitude and clearness of air, for observations of the Zodiacal Light; that the air over the Pacific Ocean appears clearer and better adapted for observations than that lying over the Atlantic Ocean; and that from high upland plains the Light must present a magnificent spectacle.

A FEW REMARKABLE OBSERVATIONS OF THE ZODIACAL LIGHT AS SEEN FROM THE PACIFIC OCEAN, FROM NOVEMBER 30, 1898, TO AUGUST 18, 1899.

Nov. 30, Dec. 1 and 2, 1898. — 7 P. M. to about 9:30 P. M. (Lat. of R. M. S. *Aorangi* being respectively 2° S., 7° S., 12° S., and Long. 172° W. to 176° W.)

During these nights the Light was distinctly visible from *Sagittarius*, in the western horizon, to *Pisces*, at the zenith, to *Gemini*, rising in the eastern horizon. Each of the three nights it was thus visible from soon after sunset until a little after moonrise, when gradually its light was absorbed about 9 P. M., 9:30 P. M., 10:15 P. M., respectively. At the western horizon the Light was diffused over some 30° of arc, gradually becoming of less extent, until at the borders of *Pisces*, 60° above the horizon, it had contracted to about 10°. To this point the Light surpassed the brilliancy of the Galaxy in *Aquila* and *Cygnus*, and thence continued as a faint but distinctly visible band, from 15° to 10° broad, across the sky until lost in the Galaxy at the eastern horizon. The line of central axis coincided with that given on pages 23-24 of this paper. Moonshine prevented further observations being made during the night. A brighter ill-defined glow, was apparent between the *Pleiades* and the Galaxy (evidently the Gegenschein), and situated on the line of central axis of the band.

January 16th — Midnight.

R. M. S *Aorangi*.—Lat. 18° N.; Long. 160° W.

Moonset, 10:45 P. M. Light nearly equal to the Galaxy from *Pisces* (western horizon) to near the Galaxy in *Taurus*. Then between 11 P. M. and midnight perfectly discernible, though very dim and diffused, from the Galaxy in the zenith through *Gemini* and *Cancer*, where it brightened a little (the Gegenschein), widely diffused through *Leo* into *Virgo* and *Corvus* at the eastern horizon. After 11 P. M. the sky was remarkably clear — had it been only moderately so, the only trace of the eastern Light would have been a bright glow over the eastern horizon, as had been seen the previous night in *Virgo* and *Leo*, 30° high, and also on the succeeding night to the same extent.

February 1st — 8 - 11:30 P.M.

R. M. S. *Aorangi*, at Comox, Vancouver I.— Lat. 49° 25′ N.

Very clear, frosty night. Thermometer 20°. Western cone bright as the Galaxy in *Perseus* to the *Pleiades*, about 65° altitude. Twenty degrees broad in *Aries*, lower portion apparently enormously displaced to the northward, but land interfered with observations at a low altitude, as did the Galaxy at very high ones. However, the band was distinctly visible from *Gemini* to near eastern horizon below the Sickle. After 11:30, clouds formed.

July 1st — 7 - 7:30 P.M.

R. M. S. *Aorangi*.— Lat. 1° N.; Long. 169° W.

Light extraordinarily bright over western horizon, to an altitude of about 20° and breadth of 60°, extending from the head of the Lynx to *Monoceros*. Intensity nearly equaled that of a second-magnitude star, the only stars in *Leo Major* which could be distinguished in its glow being α, β, γ. The Galaxy could not be compared to it. Above *Leo* it assumed its ordinary breadth and intensity to a little beyond *Spica*, over 90° from the western horizon. After 8 P.M. ordinary conditions prevailed, until cirrus haze spoilt further observations at 11:30 P.M., a faint glow having hung over the eastern horizon in *Aquarius* and *Capricornus* since 10:30. At midnight this eastern glow had increased in intensity, but moonrise, soon after 2 A.M., put an end to observations.

July 3d — 0:30 - 2:30 A.M.

R. M. S. *Aorangi*.— Lat. 9° N.; Long. 167° W.

Sky totally overcast till midnight; then clouds dispersed, leaving the heavens beautifully clear. From 0:30 to 2:30 A.M. the east branch was distinctly visible, being bright and cone-shaped within *Aries* and *Cetus* up to the Southern Fish; then faintly diffused light some 17° broad through *Aquarius* and *Capricornus*; then, very faint, it continued through *Sagittarius* into the Galaxy, broadening out into the Gegenschein at the border of the Galaxy around σ, τ, χ, ο, ν *Sagittarii*. The western branch was too low to be suitable for observation. At 2:30 A.M. clouds again formed. The following evening, from 9 P. M. to midnight, through breaks in the clouds, the Light could be seen in *Leo*, *Virgo*, and *Libra;* the Gegenschein was also visible; and a slight glow over the eastern horizon in *Capricornus*, *Aquarius*, and *Pisces*.

The evening of July 4th (Lat. 15° N.; Long. 162° W.), also corroborated the visibility of the Light in the above-mentioned constellations,—and probably in *Scorpio* also,—over both eastern and western horizons, from 9 P.M. to midnight, when clouds formed. The Gegenschein was also visible.

On the evening of July 5th, 7:45 to 8:15 P.M., the Light was intensely bright, practically equal in intensity to a second-magnitude star, to an altitude of 20° above western horizon (in *Leo*), with a maximum breadth of only 15°, there being no diffused light visible. At 9:30 P.M., the Gegenschein was inclosed by the stars 1° south of σ, τ, χ, ψ, π, ο, ζ, ν *Sagittarii*. Clouds interfered later.

July 6th—8 - 9 P.M.

R. M. S. *Aorangi*, off Isle of Oahu, H. I.

Light equal to star of magnitude 2.5, again in *Leo;* then gradually declined. Much broader than last night, with a big northerly displacement (nearly to μ *Ursæ Majoris*). Gegenschein as last night, perhaps a little more easterly. At midnight eastern horizon had a good glow over it.

July 7th.—Very good bright observations again obtained till midnight of both western and eastern branches and of the Gegenschein.

July 8th. (Lat. 30° N).—Throughout the entire night no clouds came to spoil observations, so that the Light could be seen uninterruptedly from horizon to horizon, and also the Gegenschein, during all the night. From 3 to 4 A.M., the east branch was magnificently bright. During this night the Light was visible in every zodiacal constellation excepting *Cancer* and *Gemini*, the two nearest the Sun.

Another fine "run of luck" was experienced when bound south, from August 5th (Lat. 15° N.) to August 18th (Lat 30° S.). The outlines, as well as my "home-made" charts would allow, are given, and show apparent change in the line of central axis as we proceeded south.

August 5th, 8 P. M., to *August 6th*, 3 A. M.

R. M. S. *Aorangi.*—Lat. 15°-14° N., Long. 161½° W.

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
2° N. β *Leonis.*	1° N. β *Virginis.*	About 2° N. θ *Crateris.*
3° N. δ *Virginis.*	η "	2° N. δ *Corvi.*
1° N. ζ "	2° N. α "	3° N. γ *Hydræ.*
5° S. μ "	1½° S. α *Libræ.*	5° N. π "
4° S. β *Libræ.*		2° N. *20 Libræ.*
[Galaxy intervenes.]		
ο *Sagittarii.*	2½° S. π *Sagittarii.*	1° N. σ *Sagittarii.*
1° S. β *Capricorni.*	θ *Capricorni.*	ψ "
ξ *Aquarii.*	Just N. σ *Aquarii.*	1° S. χ *Capricorni.*
Just S. γ and η "	ε *Piscium.*	δ *Aquarii.*
β *Piscium.*	τ *Arietis.*	4° N. ι *Ceti.*
4½° S. γ *Pegasi.*	1° S. *Pleiades.*	Just S. *20* "
β *Arietis.*		2° S. ν *Piscium.*
ζ *Persei.*		δ *Tauri.*

8–9 P.M.—A faint diffused light visible over the western horizon. Line of central axis not as far north as when I last saw it, in Lat. 42° N.

10 P.M.—Night clearer. Gegenschein distinctly visible in the center of the body of the Goat.

11 P.M.—The Gegenschein has faint bands extending 4° broad east and west. Westward in *Capricornus* and *Sagittarius;* eastward through *Aquarius* and *Pisces* to *Aries* at the horizon, being cone-shaped between *Pegasus*, *Pisces*, and *Cetus*.

0–0:30 A.M.—Eastern branch faintly visible from horizon, *Taurus* to Galaxy.

3 A.M.—Eastern branch distinctly visible to Galaxy. Gegenschein distinct.

The above outlines were obtained in the course of the night.

August 6th— Lat. 11° N.

8–10 P.M.—Night cloudy. Observations of the western branch and Gegenschein only obtained.

August 7th — Lat. 6° N; Long. 167° W.

8 – 10 P.M. — Cloudy. Western branch moderately distinct — widely diffused through *Virgo*, *Libra* to Galaxy. Gegenschein visible.

11 – Midnight.—Sky clear. Gegenschein distinct, but boundaries vague — oval-shaped roughly, lying between 2° or 3° north of τ and 29; θ, ε, κ, δ *Capricorni*, 2° south of λ *Aquarii*. Eastern branch visible from *Aries* to Galaxy.

1:30 A.M.—Very good observations. Light quite plain, from a little north of *Pleiades* to Galaxy.

Outlines obtained this night are contained in the next list.

August 8th — Lat. 1° N.; Long. 170° W.

8:30 P.M.—Light moderately bright, nearly equal to Galaxy; visible from *Virgo* (western horizon) round to *Aquarius* over eastern horizon, including the Gegenschein.

9 P.M.— Could distinguish connecting bands from Gegenschein to Galaxy, and Gegenschein to 10° above eastern horizon.

10 P.M. — This eastern branch more distinct from *Cetus* to Galaxy.

10 – Midnight. — Cone-shaped glow from *Aries* (eastern horizon) to Galaxy, quite distinct. Gegenschein region during the nights of the 5th, 6th, 7th, and 8th, was very puzzling and irregular. It appeared as an oval-shaped luminosity contained between curves drawn from 2° south of λ *Aquarii*, 1° north of θ *Capricorni*, η, χ, ζ 36, υ, μ *Capricorni*. South of the curve, μ, υ, *36 Capricorni*, there seemed to be no light at all, and then another bright narrow curve surrounding *36* ε, κ, δ, υ, μ *Capricorni*. The whole region being in the Zodiacal band.

1 A.M. – 3:30 A.M.— Beautifully clear night. Eastern branch very distinct from horizon (*Aries*) to the Galaxy (*Sagittarius*). Outlines given in next list. Cloudy at 4 A.M.

August 9th — Lat. 4½° S.; Long. 172° W.

8:30 – Midnight.— Cirrus haze and cumulus prevalent. At intervals west branch fairly bright. East branch well visible as before; also, the Gegenschein, the dark southern portion not being so plainly marked. Observations most satisfactorily corroborated previous nights. These outlines are now given :—

Outlines of the Light seen on August 7th, 8th, 9th.

R. M. S. *Aorangi* — Lat. 6° N. to 4½° S., Long. 167° to 172° W.

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
ε *Virginis.*	3½° S. γ *Virginis.*	γ *Corvi.*
τ "	1½° N. α "	2° N. γ *Hydræ.*
μ "	1° S. α *Libræ.*	1½° N. π "
2° N. β *Libræ.*	δ *Scorpii.*	Just N. *40 Libræ.*
48 "		
1° N. χ "		
[Galaxy intervenes.]		
Bet'n ξ and ο *Sagittarii.*	σ *Sagittarii.*	ζ *Sagittarii.*
1° S. β *Capricorni.*	ψ "	*c* "
Just S. ξ *Aquarii.*	1° S. θ *Capricorni*	1° S. ξ *Aquarii.*
" S. γ and η *Aquarii.*	μ "	2° S. δ "
β *Piscium.*	λ *Aquarii.*	ι *Ceti.*
3° S. γ *Pegasi.*	ζ *Piscium.*	Just N. α *Piscium.*
α *Arietis.*	Just N. of Ecliptic.	" N. ν *Ceti.*

August 10th.

R. M. S. *Aorangi.* — Lat. 9½° S.; Long. 175° W.

9 P.M. — After moonset west branch fairly bright — brighter than of late — to the Galaxy. Outlines much as before, but not quite so far north. Gegenschein visible from 8 P.M., nearly circular, with blank space as before; but the whole Gegenschein is brighter than of late, and the blank space showed the slightest luminosity, though still darker than the surrounding portions, towards 11 P.M., when it was overhead.

10 P.M. — Night magnificently clear. East branch quite distinct and very broad, rather more to the south than of late. The full outlines easily seen were 19° broad, across the sky, the broadest I have yet seen the connecting band. Its center was brighter and more concentrated for a breadth of 10°, and the Gegenschein formed part of this brighter central portion.

Midnight. — The Light formed a uniform broad path of luminosity across the sky, fully equal to the less illuminated parts of the Galaxy.

1 A.M. — Still continued to a uniform breadth of 19° or 20° from the *Pleiades* to the Galaxy in *Sagittarius*, and appeared so strikingly that I woke up our fourth officer to witness the spectacle. The Gegenschein appeared as a brighter patch in the

midst of the band, with a darker central portion, which was the darkest portion of the sky in the track of the Light — from *Taurus* to *Sagittarius* — i. e. from the eastern horizon to some 40° above the western.

4 – 5 A.M.—Light very distinct, forming a cone fully equal to a third-magnitude star, from eastern horizon between *Procyon* and about *51 Aurigæ*, then maintained a contracted uniform breadth of 15° to 12° to the Galaxy in western horizon. The bright cone was of uniform brilliancy throughout, and crossed the Galaxy, which was not visible at all.

Outlines given in next list.

August 11th — Lat. 14° S.; Long. 178° W.

11:45 P.M. — Overcast until now. Clouds moving away from the eastward, leaving that direction intensely clear.

0 – 0:15.—Eastern branch *ridiculously* bright, equal to the normal condition of the Galaxy, for which it has just been mistaken by a friend! — from horizon to the Gegenschein, the light being uniformly distributed in breadth and intensity, as last night.

Last night's outlines will do. Gegenschein showed the darker patch again with slightest luminosity.

Outlines are now given: —

As seen on August 10th and 11th.

R. M. S. *Aorangi* — Lat. 9° to 14° S ; Long. 175° to 178° W.

NORTHERN BOUNDARY.	LINK OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
1° N. δ *Virginis.*	4½° S. γ *Virginis.*	δ *Corvi.*
ζ "	1° S. α "	1° N. γ *Hydræ.*
1° S. δ *Libræ.*	4½° S. α *Libræ.*	π "
Bet'n η and γ *Libræ.*	1° S. α *Scorpii.*	3° S. *40 Scorpii.*
2° N. ν *Scorpii.*		
[Galaxy intervenes.]		
2° N. ξ *Sagittarii.*	τ *Sagittarii.*	γ *Corollæ.*
β *Capricorni.*	½° N. χ *Capricorni.*	2° N. α *Microscopii.*
ξ *Aquarii.*	2° S. ι *Aquarii.*	2° N. η *Piscis Aust.*
η "	2° S. λ "	2° N. *88 Aquarii.*
β *Piscium.*	1° S. Dec.; R. A. 0^{h}	2° S. ι *Ceti.*
1° S. γ *Pegasi.*	ζ *Piscium.*	5° N. θ "
1° N. α *Arietis.*	1° S. δ *Tauri.*	2° N. γ "
ζ *Persei.*	3° S. β "	o *Tauri.*
2° N. θ *Aurigæ.*	1° N. ε *Geminorum.*	4° S. α "
About *51* "	3° N. δ "	2° S. ν *Orionis.*
		Procyon.

My next observations were obtained (owing to cloudy weather) from midnight to 1:30 A.M., on August 15th, in latitude 19° S. Light was discernible from *Aries* to the Galaxy; not as clear as on the 11th and 12th, but still forming a broad band. Gegenschein but little brighter than the band, with a darker interior as before. On August 16th, Lat. 22° S., Moon set at 1 A.M., and Light was again very distinct, with same outlines as last given from Gegenschein to *Aquarius*, then southern border remained the same to 2° north of α *Ceti*, whilst northern border was foreshortened, passing 2° south of η *Aquarii*, thus placing line of central axis slightly to the southward of that given in the above list. Gegenschein region very indistinct and puzzling,—the band is very faint there,—and I do not believe the Gegenschein itself is visible.

On the mornings of the 17th and 18th, between 4 and 5 A.M., the Light was fairly bright—traceable to about 40° from the western horizon. No Gegenschein was discernible.

A long stay ashore in Sydney then interfered with my observations.

Below are given the outlines of the Zodiacal band as obtained from observations taken in both north and south latitudes. They give an extreme breadth to the band of 29°–30°. To an observer in a fixed locality the average breadth appears about 22° only, at the favorable elongation of 40° from the Sun; but if he were to move to the northward or southward he would find the northern or southern boundary extending, and thus this extreme limit of 29° – 30° has been obtained.

Extreme Outlines of the Zodiacal Band (and Normal Line of Central Axis) Forming a Band About 29° Broad Across the Entire Sky.

Northern Boundary.	Line of Central Axis.	Southern Boundary.
2° N. γ *Pegasi.*	Just S. δ *Piscium.*	2¾° S. ι *Ceti.*
α *Triang.*	Just N. ε *Arietis.*	1° S. α *Piscium.*
4° S. β *Persei.*	*Pleiades,* just N. η *Tauri.*	ο *Tauri.*
1½° N. η *Aurigæ.*	Just S. β *Tauri.*	4° S. α "
2° S. β "	1½° S. β *Geminorum.*	1° S. ν "
10¾° N. α *Gemin.*	1½° N. γ *Cancri.*	1° N. ζ *Geminorum.*

1° N. α *Lyncis.*	1½° S. η *Leo. majoris.*	1½° N. β *Cancri.*
1¾° N. δ *Leo. min.*	σ "	1½° N. ζ *Hydræ.*
2¾° N. ζ *Virginis.*	β "	4½° N. μ *Sextan.*
μ "	1° S. α "	1° N. γ *Corvi.*
2¼° S. ζ *Ophiuchi.*	3½° N. *20 Libræ.*	2¼° N. γ *Hydræ.*
4½° S. ν "	Just N. π *Scorpii.*	4¾° S. π "
3½° N. *e Sagittarii.*	1° S. α "	6½° N. κ *Centauri.*
1° N. ε *Aquarii.*	1½° N. δ *Sagittarii.*	Just N. θ *Scorpii.*
1° N. μ "	τ "	2° N. ι *Sagittarii.*
1° N. β "	Just N. χ *Capricorni.*	1¼° S. η *Piscis Aust.*
1° S. α "	2° S. ι *Aquarii.*	ε " "
4½° N. γ *Piscium.*	2½° S. λ "	Just S. *98 Aquarii.*
	R. A. 0^h; Dec. 0°.	*104* "

The above are the outlines as they appear to me, deduced from observations in all latitudes from 55° N. to 55° S.

It also seems to me that to a northern observer the northern boundary will appear about the same, and the southern boundary less southerly than here given, with a consequent displacement to the northward of the line of central axis of about 1° for every 19° of latitude he is distant from that part of the sky he is observing (*vice versa* in southern latitudes). At times, also, the band appears broader than here given, as if the Light extended still farther; but so faint, attenuated, and vague are such boundaries, that I have ignored them.

Extreme accuracy must not be expected, for only star-charts of a primitive nature have been employed for laying off my observations.

R. M. S. "WARRIMOO," VANCOUVER, B. C., Dec. 4, 1899.

OBSERVATIONS OF VARIABLE STARS.

BY ROSE O'HALLORAN.

(Continuation of observations in No. 71 of these *Publications*.)

Oct. 22. ο *Ceti* is slightly less than ξ *Piscium* in brightness.
28. Ditto.
31. Scarcely brighter than *69 Ceti* on a clear dark sky.
Nov. 21. Equal to *71 Ceti.*

29. It seems less than *71*.
30. It seems equal to *71*.
Dec. 1. Less than *71*.
2. Ditto.
5. Ditto.
8. Equal to the star of 8.2, magnitude south of *71*.
17. It is less than 8.2, but brighter in moonlight than adjacent star of 8.4 magnitude.

Oct. 22. *W Lyræ* is brighter than an adjacent star classed as of 12th magnitude, and equal to one classed as 10th.
23. Ditto.
28. Brighter than 10th magnitude, but not as bright as one to the north classed as 8.6; it is probably of about 9th magnitude.
31. It has undergone a rapid decrease, and is again of 10th magnitude.
Nov. 1. Ditto.
4. It is now of 9th magnitude.
6. Ditto.
21. It is brighter than 9th magnitude, but not equal to star of 8.6 magnitude.
22. There is a slight decrease.
29. Probably of 9th magnitude.
30. Ditto.
Dec. 1. Ditto.
2. Ditto.
3. Ditto.
5. Ditto.
6. Ditto.
17. It equals a comparison star of 8.6 magnitude.

San Francisco, 1899.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1900.

By Malcolm McNeill.

March.

The Sun passes the vernal equinox and Spring begins March 20th, 5 P. M., P. S. T.

At the beginning of the month *Mercury* is an evening star, setting an hour and twenty minutes after the Sun. This interval increases slightly until March 8th, when the planet reaches greatest east elongation. After that the distance between Sun and planet rapidly diminishes, and inferior conjunction is reached on March 24th, when the planet changes to a morning star. The March elongation and the one which will come early in July afford the best opportunities of the year for seeing *Mercury* in the evening.

Venus is an evening star well out toward greatest east elongation. It is still increasing its distance from the Sun, and is moving rapidly eastward and northward among the stars. At the end of the month it sets nearly four hours after sunset. It moves from the constellation *Aries* into *Taurus*, and at the end of the month it is near the *Pleiades*, a little south and west.

Mars still keeps its position as a morning star, rising about half an hour before sunrise. Its apparent distance from the Sun increases a little during the month.

Jupiter rises earlier, at 1:14 A. M. on March 1st, and at 11:20 P. M. on March 31st. It is still in the constellation *Scorpio*, and moves slowly eastward about 1° among the stars until March 27th, when it becomes stationary, and then moves slowly westward.

Saturn by the close of the month rises about 1 A. M. It is in the constellation *Sagittarius*, and moves slowly eastward with diminishing rapidity, as it has nearly reached its stationary point. It will be occulted by the Moon on the morning of March 24th, the occultation lasting from 1:31 to 2:38 A. M. at Washington local time. Times for other parts of the country must be determined separately.

Uranus is near *Jupiter*, in the constellation *Scorpio*. It moves eastward a little until March 17th, and then begins to move westward. At the end of the month it is 2° east and 1° south of *Jupiter*.

Neptune is still on the border of *Taurus* and *Gemini*, nearly stationary.

APRIL.

Mercury is a morning star throughout the month, and comes to greatest west elongation on April 21st. At this date its apparent distance from the Sun is 9° greater than at the greatest east elongation in March; but the planet in April is so far south of the Sun in declination that it will not be easy to see, the interval between the rising of the planet and sunrise being less than an hour.

Venus is an evening star, and reaches greatest eastern elongation on April 28th, when its apparent distance from the Sun is 45° 35′. Throughout the month it sets about four hours after sunset. It moves from a position near the *Pleiades* in *Taurus* into *Gemini*, 34° eastward and 6° northward, during the month.

Mars is still close to the Sun, and by the close of the month rises about an hour before sunrise, too short an interval to allow the planet to be seen unless under exceptional conditions of weather.

Jupiter rises two hours earlier than during March, and is getting into position for late evening observation. It is retrograding, moving westward in the constellation *Scorpio*, the motion being about 2° during the month, and is almost exactly following the path marked out by its motion in the early part of the year.

Saturn is almost stationary among the stars, moving a little eastward to April 14th, and then moving westward. It rises about two hours earlier than during March.

Uranus is still in the neighborhood of *Jupiter*, and, like it, is retrograding; but the greater westward motion of *Jupiter* causes their apparent distance to increase from 2°, on April 1st, to 3°, on April 30th.

Neptune moves about 1° eastward on the border of *Taurus* and *Gemini*.

EXPLANATION OF THE TABLES.—The phases of the Moon are given in Pacific Standard time. In the tables for Sun and planets, the second and third columns give the Right Ascension and Declination for Greenwich noon. The fifth column gives the local mean time for transit over the Greenwich meridian. To find the local mean time of transit for any other meridian, the time given in the table must be corrected by adding or subtracting the change per day, multi-

plied by the fraction whose numerator is the longitude from Greenwich in hours, and whose denominator is 24. This correction is seldom much more than 1^m. To find the standard time for the phenomenon, correct the local mean time by *adding* the difference between standard and local time, if the place is west of the standard meridian, and *subtracting*, if east. The same rules apply to the fourth and sixth columns, which give the local mean times of rising and setting for the meridian of Greenwich. They are roughly computed for lat. 40°, with the noon Declination and time of meridian transit, and are intended as only a rough guide. They may be in error by a minute or two for the given latitude, and for latitudes differing much from 40° they may be several minutes out.

MARCH-APRIL, 1900.

PHASES OF THE MOON, P. S. T.

			H. M.
First Quarter,	March	7,	9 34 P.M.
Full Moon,	March	16,	12 12 A.M.
Last Quarter,	March	23,	9 36 P.M.
New Moon,	March	30,	12 30 P.M.
First Quarter,	April	6,	12 55 P.M.
Full Moon,	April	14,	5 2 P.M.
Last Quarter,	April	22,	6 33 A.M.
New Moon,	April	28,	9 23 P.M.

THE SUN.

1900	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Mar. 1,	22 48	− 7 38	6 38 A.M.	12 13 P.M.	5 48 P.M.
11,	23 25	− 3 46	6 22	12 10	5 58
21,	0 2	+ 0 10	6 7	12 7	6 7
Apr. 1,	0 42	+ 4 29	5 49	12 4	6 19
11,	1 18	+ 8 15	5 33	12 1	6 29
21,	1 55	+ 11 48	5 19	11 59 A.M.	6 39
May 1,	2 33	+ 15 1	5 5	11 57	6 49

MERCURY

Mar. 1,	23 46	− 1 9	7 15 A.M.	1 11 P.M.	7 7 P.M.
11,	0 25	+ 5 32	6 51	1 10	7 29
21,	0 20	+ 5 58	6 6	12 26	6 46
Apr. 1,	23 51	+ 0 43	5 12	11 14 A.M.	5 16
11,	23 51	− 2 2	4 41	10 34	4 27
21,	0 18	− 0 48	4 23	10 21	4 19
May 1,	1 1	+ 3 25	4 14	10 25	4 36

Venus.

Mar. 1,	1 10	+ 7 34	8 9 A.M.	2 35 P.M.	9 1 P.M.
11,	1 54	+ 12 28	7 56	2 39	9 22
21,	2 38	+ 16 54	7 45	2 44	9 43
Apr. 1,	3 28	+ 21 1	7 35	2 50	10 5
11,	4 13	+ 23 54	7 28	2 56	10 24
21,	4 59	+ 25 52	7 26	3 2	10 38
May 1,	5 43	+ 26 51	7 26	3 7	10 48

Mars.

Mar. 1,	22 12	− 12 20	6 18 A.M.	11 36 A.M.	4 54 P.M.
11,	22 42	− 9 27	5 59	11 27	4 55
21,	23 11	− 6 25	5 39	11 17	4 55
Apr. 1,	23 43	− 2 59	5 15	11 5	4 55
11,	0 11	+ 0 9	4 55	10 54	4 53
21,	0 39	+ 3 15	4 32	10 43	4 54
May 1,	1 8	+ 6 17	4 11	10 32	4 53

Jupiter.

Mar. 1,	16 33	− 21 5	1 14 A.M.	5 59 A.M.	10 44 A.M.
Apr. 1,	16 38	− 21 11	11 17 P.M.	4 1	8 45
May 1,	16 30	− 20 55	9 11	1 56	6 41

Saturn.

Mar. 1,	18 15	− 22 24	3 1 A.M.	7 40 A.M.	12 19 P.M.
Apr. 1,	18 21	− 22 21	1 6	5 45	10 24 A.M.
May 1,	18 21	− 22 20	11 7 P.M.	3 46	8 25

Uranus.

Mar. 1,	16 44	− 22 14	1 29 A.M.	6 9 A.M.	10 49 A.M.
Apr. 1,	16 45	− 22 14	11 27 P.M.	4 7	8 47
May 1,	16 41	− 22 9	9 26	2 6	6 46 A.M.

Neptune.

Mar. 1,	5 35	+ 22 4	11 40 A.M.	6 59 P.M.	2 18 A.M.
Apr. 1,	5 36	+ 22 6	9 42	5 1	12 20
May 1,	5 39	+ 22 9	7 46 A.M.	3 6	10 26 P.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

			H.	M.					H.	M.	
II, R,	Mar.	2,	11	42	P.M.	II, D,	Apr.	3,	8	52	P.M.
III, D,		6,	11	34		I, D,		6,	4	10	A.M.
III, R,		7,	1	8	A.M.	I, D,		7,	10	38	P.M.
I, D,		7,	2	8		II, D,		10,	11	26	
II, D,		9,	11	55	P.M.	III, D,		11,	7	22	
II, R,		10,	2	15	A.M.	III, R,		11,	9	1	
III, D,		14,	3	31		I, D,		15,	12	31	A.M.
III, R,		14,	5	6		II, D,		18,	2	1	
I, D,		15,	10	29	P.M.	III, D,		18,	11	19	P.M.
II, D,		17,	2	28	A.M.	III, R,		19,	12	58	A.M.
II, R,		17,	4	49		I, D,		22,	2	25	
I, D,		21,	5	54		I, D,		23,	8	53	P.M.
I, D,		23,	12	23		I, D,		25,	4	35	A.M.
II, D,		24,	5	2		III, D,		26,	3	16	
I, D,		30,	2	16		III, R,		26,	4	57	
						I, D,		29,	4	19	
						I, D,		30,	10	47	P.M.

(THIRTY-SEVENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. E. GIACOBINI, of the Nice Observatory, for his discovery of an unexpected comet on September 29, 1899.

The Committee on the Comet-Medal,

JAMES E. KEELER,
WM. M. PIERSON,
CHAS. BURCKHALTER.

1899, December 2.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DOUBLE-STAR NOTES.

The weather in the year 1899, taken as a whole, was not as favorable for double-star observations as during the year or two preceding. In the first three months, and again in the last three months, of the year, long spells of stormy or cloudy weather interfered seriously with the continuity of observations; and the month of August, usually a good observing month, had but very few nights when the seeing was good enough for the measurement of close pairs. Two hundred and fifty-five double stars were, however, measured during the year, 154 of them being under 1" in distance, and many of them near the limit of the separating power of even the large refractor.

This list includes nearly all the more rapid binary systems, many of the more difficult β stars, and forty-seven new pairs, all under 5", which were found with the twelve-inch telescope. The detailed measures will be published in the *Astronomische Nachrichten;* but notes on some of the more important stars will be of interest.

Procyon: Measures of SCHAEBERLE'S companion on three nights give the following position:—

1899.99 334°.5 4".88

SCHAEBERLE'S discovery position was—

1896.874 318°.8 4".59

The companion is very faint—not brighter than 13½ magnitude—and can only be seen well enough for good measures on the best nights. It is now much harder to measure than the companion to *Sirius.*

Sirius: The companion is increasing its distance from the bright star, and continues its motion in angle. The means of five measures in angle and four in distance, including measures on one night in this year, are:—

---

* Lick Astronomical Department of the University of California.

1899.896 145°.6 4″.53

ZWIERS's ephemeris gives for the same date, 147°.2 4″.55.

β 883: This close and interesting pair was measured on ten nights during the year. The mean of the measures on the last two nights is —

1899.906 56°.5 0″.24

Since I began observing this pair in the autumn of 1896, I have measured it on thirty-two different nights — the longest intervals between two successive measures in the past two years being 0.4 years in the spring of 1898, and 0.3 years in the spring of 1899. As the angular change in three years, from 1896.88 to 1899.91, has been only 40°, I think it is now safe to say that this system cannot have a period at all approximating five and a half years. In fact, it seems very possible that the period may finally be found to be more nearly twenty years, as the consecutive character of the measures makes it practically certain that no change of quadrant has taken place in the last two years.

φ Andromedæ: Measures of this pair on three excellent nights in July give:—

1899.557 231°.0 0″.23

The smaller star has been assumed to be in the first quadrant for the last few years; and the angular change since discovery in 1851 as more than 250°. But on these three nights the quadrant was noted with particular care, and as the difference of brightness of the components is nearly one magnitude, and the atmospheric conditions were most favorable, the position here given is undoubtedly correct. The period of revolution of this pair, too, is therefore much greater than has been supposed.

β 1007: This is one of the pairs found by BURNHAM with the twelve-inch refractor during his stay on Mt. Hamilton, in November, 1881. The mean of two nights' measures then gave:—

1881.86 266°.2 0″.27

Subsequently, BURNHAM was unable to see the star double with the 18½-inch Dearborn refractor; and in the years 1890–92 he noted it as single with the thirty-six-inch refractor. During the past year the companion has again appeared in the same quadrant as in 1881. A measure in 1899.177 gave 244°.3 0″.18, and two later measures give as mean:—

1899.724 243°.2 0″.22

The star is apparently in rapid motion, probably in an orbit whose plane is nearly parallel to the line of sight.

β 524 = 20 Persei. This is one of the closest pairs measured during the year. The four measures secured are:—

1898.925	47°.6	0″.12
1899.180	31 .4	0 .12
.555	49 .2	0 .13
.557	50 .2	0 .14

The angle given by the second measure is not in good accord with the other values, and may contain an error of circle reading. The pair, however, is so close and difficult under the best conditions that I have not felt at liberty to reject the discordant measure. BURNHAM's discovery position was —

1878.66 338°.7 0″.34

and his last measure with the thirty-six-inch refractor,—

1891.79 281°.7 0″.15

If the above positions are correct as to quadrant, the pair has, therefore, nearly completed a revolution since discovery.

Some of the other close pairs measured during the year are:—

β 1146,	1899.56	313°.6	0″.18
κ *Pegasi*,	1899.4	284 .0	0 .19
Secchi = BC of Σ *2481*,	1899.69	187 .9	0 .16
β 1185,	1899.92	347 .0	0 .14
Σ *1865*,	1899.53	161 .6	0 .16
Σ *1989* = π^2 *Ursæ Min.*,	1899.53	347 .6	0 .16

Eighteen other pairs, with distances of less than one quarter of a second of arc, were measured during the year, the closest pair of all being perhaps *β 953*, of which measures were possible on only one night. These give —

1899.714 223°.2 0″.10

In 1898 the star was found to be single.

R. G. AITKEN.

January, 1900.

COMETS OF 1899.

Five comets in all were discovered during 1899. Of these two only were new, the remaining three being apparitions of short-period comets.

Comet *a* (1899 I) was discovered on March 3, 1899, by Dr. SWIFT, at the Lowe Observatory, Echo Mountain, California. At the time of discovery the comet was moving north and towards the Sun, which it passed on April 12th. During some weeks it was lost while near the Sun, but was picked up again early in May. It attained a north Declination of 57° on May 29th. After perihelion passage, which occurred on April 13th, the comet became much brighter, being estimated at 3.0 magnitude on May 7th (HOLETSCHEK).

On May 11th, a second nucleus was observed, which was visible for two weeks.*

The last observation at Mt. Hamilton was on July 31st.

Comet *b* (1899 III), TUTTLE'S periodic comet, was rediscovered by Dr. MAX WOLF, at Heidelberg, by means of photography, on March 5th. It was then of 12th magnitude. Its brightness increased as it approached perihelion, which was passed on May 4th. It was last observed in the northern hemisphere on May 1st, when it became lost in the rays of the Sun. After perihelion passage it was observed in the southern hemisphere. This comet has a period of 13.8 years, and was observed at its last return in 1885.

Comet *c* (1899 IV), TEMPEL'S second periodic comet, was rediscovered by the writer on May 6th. It was then of about the 16th magnitude, but increased rapidly in brightness as it neared both Sun and Earth. It passed perihelion on July 28th, at which time it was almost in opposition, and only thirty-five million miles distant from the Earth. At this time its brightness was of about the 8th magnitude. This opposition was one of the most favorable possible of this comet. It was last observed at the Lick Observatory on December 1st, when it was of only the 15th magnitude. This comet was observed on its last return to perihelion in 1894.

Comet *d* (1899 II), HOLMES'S periodic comet, was rediscovered by the writer on June 10th. It was then very faint—being estimated at 16th magnitude. This comet attracted much attention at the time of its discovery in 1892, when it was visible to the unaided eye. Its situation was practically as favorable for observation at this appearance as in 1892–93, and yet it has not been brighter than the 14th magnitude.

---

* *Publications A. S. P.*, No. 69, p. 150.

Perihelion was passed on April 28th. The last observation at Mt. Hamilton was on December 24th.

Comet *e* (1899 V) was discovered by M. GIACOBINI, at Nice, on September 29th. It was then of about the 11th magnitude. Perihelion was passed on September 15th, at a distance of one hundred and sixty-five million miles. Its brightness has decreased slowly. At the last observation, of December 23d, it was estimated to be of the 13th magnitude. It is now too near the Sun to be observed, but will in all probability be bright enough to be observed with large instruments in February or March.

C. D. PERRINE.

1900, January 20.

NOTE ON THE SPECTRUM OF COMET *a* 1899 (SWIFT).

The spectra of the brightest comets of 1898 and 1899 were carefully observed at the Lick Observatory by Mr. WRIGHT. His paper describing the results is published in the *Astrophysical Journal* for October, 1899. One fact established by the observations of SWIFT'S Comet (1899 *a*) seems to me to be of great interest and importance.

Mr. WRIGHT'S photograph of the spectrum records some fifteen bright lines, of which the lines at wave-lengths 4052, 3880, and 3870 are the strongest. "In the spectrum of the nucleus λ 4052 is fully as bright as λ 3870, but the latter line extends out into the comet's head more than four times as far as the former. In fact, the lines λλ 3870 and 3880 experience only a gradual increase in brightness in the region of the nucleus, and extend the entire length of the slit. In the cases of all the other lines, the change is quite abrupt. This must be taken to indicate a marked difference between the spectrum of the nucleus and the spectra of the outer parts of the head."

The lines at λλ 3870 and 3880 are due to cyanogen.

It seems not too much to hope that this beginning in detecting differences in the spectra of different parts of comets may, in the case of very bright comets, be extended over larger areas and in greater detail; leading, as in the case of the Sun, to a better understanding of their condition and constitution.

W. W. C.

REDISCOVERY OF MINOR PLANET (415) [1896 CO].

This planet was discovered February 7, 1896, by Professor MAX WOLF, at Heidelberg, Germany. At that time only a few observations were obtained, and it was not seen again until I picked it up by means of its trail upon a negative obtained with the Crocker telescope, October 2, 1899. From an examination of the times and places of opposition of the minor planets, given in the *Berliner Jahrbuch*, it appeared probable that the planet was new; and I accordingly made a series of observations of it with the twelve-inch telescope. From observations of October 4th, October 26th, and November 17th, I computed the following elements of its orbit:—

Epoch, 1899, October 4.5, Berlin mean time.

$$\begin{array}{rrrrl}
\mathbf{M} = & 332^\circ & 37' & 13''.1 & \\
\omega = & 293 & 31 & 49\,.5 & \multirow{3}{*}{$\left.\begin{array}{l}\\ \\ \\ \end{array}\right\}$ 1899.0} \\
\Omega = & 128 & 13 & 1\,.7 & \\
i = & 8 & 6 & 28\,.9 & \\
\phi = & 17 & 34 & 0\,.7 & \\
\mu = & \multicolumn{3}{l}{761''.2267} & \\
\log a = & \multicolumn{3}{l}{0.445662} &
\end{array}$$

When these elements were obtained, it was seen that they were more nearly like those which Dr. BERBERICH had obtained from the 1896 observations of (415) than those of any other planet. Yet the difference between the two systems of elements was so considerable that it still appeared probable that the planet which I had found was new. This, however, was not the case. Dr. PALISA, at Vienna, searched in vain for (415) in the place given by the ephemeris published in *Veröffentlichungen des Königlichen Astronomischen Rechen-Institute zu Berlin*, No. 10, and reported his failure in *Astronomische Nachrichten*, No. 3600. My elements were communicated to the *Astronomische Nachrichten*, and by means of them Dr. KREUTZ has proven the identity of the two supposedly different planets. By computing a place from these elements for February 11, 1896, Berlin mean midnight, he obtained a position in close agreement with an observation of (415) made at Vienna on that day. I have made this computation for the exact time of the Vienna observation, and find the difference between the observed and computed places to be as follows:—

$$\begin{array}{rl}
\text{O} - \text{C:}\ \Delta\alpha = & +\ 20^s.82 \\
\Delta\delta = & -\ 25''.1
\end{array}$$

MT. HAMILTON, January 22, 1900. E. F. CODDINGTON.

THE MEXICAN EARTHQUAKE OF JANUARY 19TH OBSERVED AT THE LICK OBSERVATORY.

On the night of Friday, January 19th, the central part of Mexico was visited by a severe earthquake, which destroyed several lives, and did an immense amount of damage to buildings and other property.

This earthquake was observed at the Lick Observatory, some fifteen hundred miles from the region of greatest disturbance. At 10^h 50^m Mr. R. H. TUCKER, who was working with the meridian-circle, and had observed the transit of a star at 10^h 41^m, turned the telescope downward to the mercury-basin between the brick piers, for an observation of the nadir point. This, however, he found impossible. The mercury was oscillating from both north to south and east to west, with a period of about seven seconds. The full amplitude of the oscillation (doubled by reflection) could be estimated quite accurately by observing the excursion of the image of the cross-wires. It was very nearly $15''$. After about five minutes the oscillations began to decrease, and at 11^h 5^m had fallen to about one fourth of their maximum value. At 11^h 15^m they were still perceptible, but were no longer regular; the reflected image would come to rest for a few moments, and then continue to swing. At 11^h 30^m the vibration had so nearly ceased that the nadir observation was made. No change was found in the position of the instrument.

It will be seen that the oscillations continued for the remarkable length of time of forty minutes. There was no wind at the time, or anything to cause an unusual disturbance. A similar, though less marked, phenomenon on a previous occasion had been followed by an earthquake, though not a severe one, and Mr. TUCKER was led to expect a proportionally stronger shock after the oscillations he had observed on this night — an expectation which fortunately was not realized. It was not until January 22d that the news of the earthquake in Mexico reached Mt. Hamilton.

The thirty-six-inch refractor, the twelve-inch refractor, and the Crossley reflector were all in use, while the oscillations observed by Mr. TUCKER were in progress, but no disturbance of these instruments was noticed. It seems to me probable that there was a bodily motion of the whole surface of the ground, which would not produce an angular displacement of a telescope, though it might cause the mercury to swing in the manner observed by Mr. Tucker. No accurate data respecting the times of the most severe shocks in Mexico have yet been obtained. J. E. K.

The Binary Star, OΣ 341.

In 1898 I called attention to the change which had taken place in the relative positions of the components of this double star, and at the same time showed that the character of the motion proved it to be a binary system.

It will be remembered that the observations of this star from 1846 to 1886 gave no certain indications of motion, and, in consequence, that its components had come to be regarded as relatively fixed, at a distance of about 0".40. The observations of the past two years, however, show that the motion is quite rapid at times. During the first half of 1898, the star appeared perfectly round with the thirty-six-inch refractor, even when very high powers were used. On several occasions when the seeing was very fine, I failed utterly to detect any indication of duplicity, and Professor Aitken had the same experience. In the latter part of the same year the distance had increased, and a very slight elongation could be seen, the measured distance being 0".10, and in another year it had increased to nearly 0".20. From this it would seem that this pair will soon become again a comparatively easy object for large telescopes under good conditions.

When an elongation was first detected in the latter part of 1898, I thought there had been a change of quadrant, but this has not been confirmed. The present position-angle differs very little from that obtained by all the earlier observers. An examination of all the observations available at the present time shows that in all probability the two stars are actually very near each other at periastron, and that the line of sight lies nearly in the plane of the orbit. From this it will be seen that the determination of the elements of the orbit of this binary, when sufficient observations for the purpose are obtained, will depend very largely upon the distances at the various epochs, and it is scarcely necessary to add that accurate measures of the distance at frequent intervals during the periods of rapid change such as the present will be particularly useful for this purpose.

January 17, 1900. W. J. Hussey.

NEW MINOR PLANET 1899 EX.

I discovered this planet by means of its trail upon a negative taken with the Crocker telescope, October 2, 1899. At that time its brightness was estimated to be about 12th magnitude. I made a series of observations of it with the twelve-inch telescope, and from those of October 4th, 15th, and 26th, computed the elements of its orbit, as follows:—

Epoch, 1899, October 4.5, Berlin mean time.

$$\begin{array}{rrrrl} M = & 2^\circ & 43' & 11''.7 & \\ \omega = & 79 & 36 & 27.4 & \multirow{3}{*}{} \\ \Omega = & 293 & 10 & 50.2 & \left.\vphantom{\begin{array}{l}a\\b\\c\end{array}}\right\} 1899.0 \\ i = & 21 & 25 & 0.6 & \\ \phi = & 11 & 50 & 32.5 & \\ \mu = & \multicolumn{3}{l}{623''.873} & \\ \log a = & \multicolumn{3}{l}{0.503274} & \end{array}$$

E. F. CODDINGTON.

MT. HAMILTON, January 22, 1900.

THE SPECTROSCOPIC BINARY, β *HERCULIS.*

The velocity of β *Herculis* in the line of sight was found to be variable, in July, 1899, while measuring the third plate of this star's spectrum obtained with the Mills spectrograph. Three additional plates confirm the variation. Our observations up to date are as follows:—

1897, June 1, -32^{km}
1898, June 13, -31.9
1899, Feb. 26, -23.3
July 31, -30.9
Aug. 21, -30.8
1900, Jan. 10, -21.0

The period of revolution is undetermined, but it appears to be comparable to a year.

W. W. CAMPBELL.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

The two astronomers whose portraits are published in this number were the recipients of the Bruce Medal of the Society in the years 1898 and 1899. Some account of the "distinguished services to astronomy" rendered by Professors NEWCOMB and AUWERS will be found in numbers 61 and 67 of these *Publications*.

The following special announcement, by President WHEELER, of the University of California, may be of interest to members of the Society residing in the neighborhood of Berkeley:—

"In connection with the course in Modern Astronomy—Astronomy 1—the following lectures will be delivered during the second half of the current academic year by Director JAMES E. KEELER, Astronomer W. W. CAMPBELL, Astronomer R. H. TUCKER, and Astronomer W. J. HUSSEY, of the Lick Astronomical Department:—

Director JAMES E. KEELER:—
- Tuesday, February 6th — The Theory and Construction of Reflecting Telescopes.
- Thursday, February 8th — The Crossley Reflector and its Work.

Astronomer W. W. CAMPBELL:—
- Tuesday, February 20th — Some Results Obtained from Measurements of Stellar Velocities in the Line of Sight.
- Wednesday, February 21st, at 8 P. M. — The Lick Observatory Eclipse Expedition to India.

Astronomer R. H. TUCKER:—
- Tuesday, February 27th — The Meridian Circle.
- Thursday, March 1st — Star Catalogues.

Astronomer W. J. HUSSEY: —
- Tuesday, March 6th, and Thursday, March 8th — Aspects of the Astronomy of Precision.

"Mr. ALEXANDER MCADIE, Honorary Lecturer on Meteorology in the University of California, and Local Forecast Official of the United States Weather Bureau in San Francisco, will deliver a series of four lectures on Meteorology, as a part of the course in Modern Astronomy. His subjects will be as follows: —

- Tuesday, March 20th — At the Bottom of the Sea.
- Thursday, March 22d — Lightning and Electricity of the Air.
- Tuesday, March 27th — Exploring the Atmosphere.
- Thursday, March 29th — Forecasting.

"Visitors will be welcome at all times. The lectures will be delivered at the regular hour of the course, 11:15 o'clock, except Professor CAMPBELL'S second one, in the new Astronomical Lecture-room of the Students' Observatory."

Professor WM. HARKNESS, Astronomical Director of the United States Naval Observatory, and Director of the Nautical

Almanac, has been retired after a service of nearly forty years in the Naval Observatory. His successors are Professor S. J. BROWN, as Director of the Naval Observatory, and Professor H. D. TODD, as Director of the Nautical Almanac. Professor BROWN is a graduate of the United States Naval Academy, and has been connected with the Naval Observatory about sixteen years, as Professor of Mathematics. Professor TODD, likewise Professor of Mathematics in the United States Navy, has been chief assistant in the Nautical Almanac Office for some years.

The Rumford Committee of the American Academy of Arts and Sciences, has appropriated the sum of $500 to Professor E. B. FROST, of the Yerkes Observatory, to assist in the construction of a spectrograph especially designed for the measurement of stellar velocities in the line of sight.—*Science, 1899, Nov. 17.*

Mr. F. E. Ross, last year Fellow in Astronomy in the University of California, has recently been appointed to the position of Instructor in Mathematics in the University of Nevada.

The library of the Society has lately received a copy of a new work, "Star-Names and Their Meanings," by RICHARD HINCKLEY ALLEN, a member of the Society. The work, published by G. E. STECHERT, New York, contains 547 pages, and presents a very neat appearance. Such a work must of necessity be incomplete, and is almost sure to contain some errors; still it also doubtless contains much that is good and valuable. In the introduction we find the following:—

> "The world-wide field of research that I have endeavored to traverse, containing the records of four or five millenniums, it need hardly be said demands for its exploration the best efforts, long continued, of the scientist and scholar accomplished in archæology, astronomy, literature, and philology. None such, however, has appeared since IDELER's day, nearly a century ago; so that, with the desire of taking up again this most interesting task, and the hope of thus stimulating others more competent to carry it on, I have done what I could, although frankly confessing that I have fallen very far short of my ideal. Originality is not claimed for my book. Much of it has been gathered from widely scattered sources, brought together here for the first time in readily accessible form, although doubtless with errors and certainly with much omission; for while I have sought, as did MILTON's *Il Penseroso*, to
>
> 'sit and rightly spell
> Of every star that heav'n doth show,'

yet in preparing my material I have seen, as Doctor SAMUEL JOHNSON wrote in the preface of his *Dictionary*,—

'that one enquiry only gave occasion to another, that book referred to book, that to search was not always to find, and to find was not always to be informed.'

So that, following him,—

'I set limits to my work, which would in time be ended though not completed.'

While to temper such criticism as may be bestowed upon my efforts, I quote again from the same source:—

'Dictionaries are like watches; the worst is better than none, and the best cannot be expected to go quite true.'"

The work should certainly be in every library.

The report of the Board of Visitors of the United States Naval Observatory, extracts from which were printed in our last number, was transmitted to Congress by the Secretary of the Navy, and has now been printed in full as Senate Document No. 19. That the committee has thoroughly investigated the condition of the observatory, past as well as present, and spent a great deal of time on the report, is plainly evident. The majority of American astronomers will, we believe, heartily indorse the report of the board. Some criticisms might be made upon it; but if the recommendations there suggested are carried out, there can be but little doubt that the efficiency of the observatory will be largely increased. Its organization and government would then be similar to that of the great national observatories of Europe, which have rendered most valuable service to astronomy for many years. It is to be hoped that the proper legislation can be gotten through the present Congress.

Mr. Benjamin S. Mayhew has sent the following observations of November meteors, made at Olive, Winnipeg, Manitoba:—

1899.
Nov. 13. 11 P.M. to 2 A.M. No meteors. Sky became overcast at 2 A.M.
14. 11 P.M. to 2:30 A.M. No meteors seen. Sky overcast from 2:30 A.M.
15. 11 P.M. till after midnight, when clouds came. No meteors seen.
16. Cloudy.
24. From 11 P.M., for several hours, meteors fell from all parts of the heavens in all directions, about eight every five minutes. Most of them were small; occasionally there was a brilliant one. For an hour before dawn they fell at about the same rate, and of similar appearance. (The shower of November 24th, above noted, was probably a portion of the *Bielid* shower from the radiant in *Andromeda*, which was reported by Professor YOUNG, as observed at Princeton.)

The following is an extract from a letter to Professor J. E. KEELER:—

> "It may be of slight interest to you to know that the *Leonids* were carefully looked for by me during the nights November 13-16th. Unfortunately, they were totally overcast, except from 4 to 5 A.M., November 15th = $14^d\ 4^h\ 30^m$ to $5^h\ 30^m$, G. M. T. (Lat. of ship being 11° S.; Long. 168½° E.). During this hour I counted about twenty shooting-stars in *Leo Major* and *Minor*, and next day (November 16th), from 4:30 to 5 A.M. = $15^d\ 4^h\ 40^m$ to $5^h\ 10^m$, G. M. T. (Lat. 7½ S.; Long. 172 E), I counted about fifteen shooting-stars, all from near γ *Leonis Majoris*, but was so disgusted with the weather that I took no notice of their paths.
>
> FRANCIS J. BAYLDON, (2d Officer), S. S. *Warrimoo*.
>
> December 4, 1899.

The *Astronomische Nachrichten*, Nos. 3606-3607, contains the definitive elements of the orbit of Comet 1894 IV (E. SWIFT) by one of the members of the Astronomical Society of the Pacific, Mr. FREDERICK H. SEARES. From a careful discussion of the seventy-five observations secured of this comet between the dates of November 21, 1894, and January 29, 1895, Mr. SEARES derives the following definitive elements:—

Epoch, 1894, Dec. 1.0. Osculation, 1894, Dec. 10.0.

$$\begin{array}{rrrrl} M_0 = & 8^\circ & 22' & 58''.2 & \pm\ 4''.2 \\ \pi = & 345 & 23 & 11\ .1 & \pm\ 4\ .4 \\ \Omega = & 48 & 48 & 23\ .4 & \pm\ 27\ .7 \\ i = & 2 & 57 & 55\ .8 & \pm\ 1\ .4 \\ \phi = & 34 & 51 & 37\ .3 & \pm\ 7\ .1 \\ \mu = & \multicolumn{4}{l}{605''.9999 \pm 0''.0665} \end{array} \quad \left.\begin{array}{l} \\ \\ \\ \end{array}\right\} 1900.0$$

In his discussion, Mr. SEARES has given especial attention to the places of the comparison-star used. "Practically all of the existing catalogues were searched," and the adopted positions depend upon a careful consideration of the relative weights of these catalogues. The effect of *Jupiter*, *Saturn*, *Mars*, and the Earth upon the positions of the comet has also been fully taken into account.

Aside from the shortness of its period — a little less than six years — this comet is interesting to astronomers, from the fact that it may be identical with the lost comet of DE VICO — 1844 I. Mr. SEARES has undertaken the investigation of this question — the calculation of the definitive elements here noticed being the first part of the work.

As the comet returns to perihelion about August 20, 1900, a search ephemeris will be of great interest to those engaged in the pursuit of comet-seeking, and we suppose that Mr. Seares will publish such an ephemeris in the near future.

Some time ago a letter was addressed to the directors of the observatories of the Pacific Coast, asking for a statement of the work accomplished at each of these institutions during the year 1899. From the answers received, the following accounts have been written:—

Chabot Observatory.—Being a part of the school system of the city of Oakland, this observatory is used chiefly for purposes of instruction. Two nights a week are set apart for classes from the schools, and special evenings are given to classes from schools and academies outside of the city. The observatory is open to the public two or three evenings of the week, and a time-service for the city of Oakland, is also maintained. Mr. Burckhalter writes, that all his spare time for several months in 1899 was spent in perfecting his apparatus for photographing the corona in the coming eclipse, which he expects to observe in Georgia. Experience at the Indian eclipse in 1898 showed some defects in the apparatus, but these have now been remedied, and Mr. Burckhalter thinks that the corona, weather permitting, cannot possibly get away from him next May.

Latitude Observatory.—Observations have been commenced at the Latitude Observatory, in Ukiah, but Dr Schlesinger reports slow progress, on account of bad weather. The first latitude observations were made on October 11th, and the following is a summary of the work accomplished from that date until the end of the year:—

1899.	Nights.	Pairs.
October	12	146
November	12	102
December	13	179
Totals	37	427

Lick Observatory.—Through the "Notices from the Lick Observatory," the readers of these *Publications* are kept pretty well informed concerning the work carried on in that institution. Director Keeler's report to the President of the University, for the year ending September 1, 1899, was printed in full in *Science*, November 10th, and is therefore not reprinted here. The report is very interesting, however, and the attention of the members of the Society is called to it. Concerning the nature and plan of the work of the observatory, we quote the following introductory remarks from Director Keeler's report: "The nature of the scientific work undertaken at the Lick Observatory is determined by such considerations as the unusually fine atmospheric conditions which prevail here, the nature of the instrumental equipment, and the number of observers on the staff. The general policy of the observatory is to carry on investigations which cannot be pursued to so great advantage elsewhere. Thus, comets which are bright enough to be easily seen at the leading observatories receive only occasional attention, while comets which, by reason of their faintness or unfavorable position, are difficult of observation, are followed as closely as possible. Elaborate investigations, dealing with large masses of data, and requiring a large force of computers, can only be undertaken by richly endowed observatories or by those which receive Government assistance. The Lick Observatory makes the most of its natural advantages; and extended theoretical researches which can be made as well in a city as at a fine observing-station do not form a part of our general plan."

LOWE OBSERVATORY.— It is gratifying to note that Dr. SWIFT, Director of the Lowe Observatory, although afflicted with failing eyesight, has been able during the past year to add a comet and several nebulæ to his long list of discoveries.

STUDENTS' OBSERVATORY.— The work at the Students' Observatory, Berkeley, is nearly all in the line of instruction, and the time of the members of the staff is given to directing and supervising the work of students rather than to research work. Professor LEUSCHNER, Director of the observatory, states that the Faculties of the University, in conjunction with the astronomers of the Lick Observatory, are now engaged in elaborating a comprehensive course of instruction, graduate as well as undergraduate, covering seven years, and leading to the degree of Doctor of Philosophy in three different lines,— Astronomy, Astrophysics, or Geodesy. A large part of the graduate work is to be done at Mt. Hamilton. We hope in a future number of these *Publications* to give a detailed account of the proposed plan. A new lecture-room has recently been added to the observatory, and this affords much needed room for accommodating the large classes in Modern Astronomy. The room is provided with every convenience for lantern-slide work, projecting spectra, etc. During the past year instruction was given in the following courses: Modern Astronomy, General Astronomy, History of Astronomy, Theoretical Astronomy, Method of Least Squares, Mechanical Quadratures, Interpolation and the Use of Tables, Graduate Course in Theoretical Astronomy, Graduate Course in Perturbations, and several courses in observatory work. During the term just past the total enrollment was 137, of whom eight were graduate students. The following may be mentioned among the special lines of work carried out by the students during the past year: Computation of the orbits of Comet 1898 VIII (CHASE) and Comet 1899 V (GIACOBINI); computation of the elements and the path of the shadow of the total solar eclipse for May 28, 1900; a determination, upon seven nights, of the difference of longitude between the Students' Observatory and the United States Coast and Geodetic Survey Observatory in San Francisco, including a least square reduction of the observations and also of all the previous determinations of longitude of the observatory.

UNITED STATES COAST AND GEODETIC SURVEY OBSERVATORY.— This observatory, situated in the Presidio Reservation, San Francisco, is used as a longitude base for the determination of new stations by telegraphic time-signals and for practice of observers. Captain AUG. F.

RODGERS, Assistant in Coast Survey, and in charge of the observatory, writes, however, that no new determinations were made during the past year.

From the *Comptes Rendus* of the 18th of December, 1899, we learn that the Lalande Prize, of 540 francs, has this year been awarded by the French Academy of Sciences to Mr. W. R. BROOKS for his record in the discovery of comets.

The Valz Prize, of 460 francs, has been awarded by the same body to M. NYRÉN, of the Pulkowa Observatory, for his work in the field of sidereal astronomy.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, JANUARY 27, 1900, AT 7.30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED JANUARY 27, 1900.

Mr. PAUL DANA	*The Sun*, New York, N. Y.
Mr. E. H. SHATTUCK	Granby, Connecticut.
THE WOMAN'S COLLEGE	Baltimore, Md.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, JANUARY 27, 1900, AT 8 P. M.

Mr. BURCKHALTER presided. The minutes of the last meeting were read and approved.

The following papers were presented:—

1. Notes on the Zodiacal Light; being a summary of observations made at sea since 1889, by FRANCIS J. BAYLDON, R. N. R.
2. Planetary Phenomena for March and April, 1900, by MALCOLM MCNEILL.

A committee to nominate a list of eleven Directors, and Committee on Publication, to be voted for at the annual meeting to be held on March 31st, was appointed as follows: Messrs. CHAS. S. CUSHING, CHARLES ALTSCHUL, HENRY J. CROCKER, D. S. RICHARDSON, JOHN R. RUCKSTELL.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed, as follows: Messrs. O. VON GELDERN, F. H. MCCONNELL, C. B. HILL.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. George C. Pardee	*President*
Mr. James E. Keeler	*First Vice-President*
Mr. Charles Burckhalter	*Second Vice-President*
Miss R. O'Halloran	*Third Vice-President*
Mr. C. D. Perrine Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Burckhalter, Campbell, Hill, Keeler, Molera, Miss O'Halloran, Messrs. Pardee, Perrine, Pierson, von Geldern, Ziel.

Finance Committee—Messrs. Pierson, von Geldern, Hill.

Committee on Publication—Messrs. Aitken, Townley, von Geldern.

Library Committee—Messrs. Townley, Geo. C. Edwards, Miss O'Halloran.

Committee on the Comet-Medal—Messrs. Keeler (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XII. SAN FRANCISCO, CALIFORNIA, APRIL 1, 1900. NO. 73.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO H. M. ASTRONOMER, DR. DAVID GILL.

BY GEORGE C. PARDEE.

Following the custom established by my predecessors, it becomes my duty this evening to make public announcement of the award of the Bruce Gold Medal of the Society.

I take great pleasure in stating that the award for this year, by unanimous vote of the Board of Directors, was made to H. M. Astronomer at the Cape of Good Hope, Dr. DAVID GILL.

Before proceeding to give the Society an account of Dr. GILL'S "distinguished services to astronomy," which so eminently entitle him to this mark of our consideration, it may not be inappropriate to call attention to the catholicity of science, and of astronomical science in particular, as exemplified in the first three awards of the Bruce Medal. Science recognizes no distinction of nationality; and while as Americans we are proud to think that an American astronomer was found worthy to be honored as our first medalist, we last year gladly recognized the right of the man who "to-day stands at the head of German astronomy" to take rank with him, and now make no less welcome the distinguished representative of English astronomy, whose work we honor to-night.

I am indebted to Professor R. G. AITKEN, of the Lick Observatory, for the collection and arrangement of the following facts concerning the astronomical work of our eminent medalist.

In a lecture delivered at the Royal Institution in 1884, Dr. GILL, after speaking of the fascination sidereal astronomy has ever had for the mind of man, of the questions without number that crowd upon the mind in contemplating the distances of space, and of the little progress that has been made in the solution of these problems, used the following language :—

> "Human knowledge in the slow developing phenomena of sidereal astronomy must be content to progress by the accumulating labors of successive generations of men; progress will be measured for generations yet to come more by the amount of honest, well-directed, and systematically discussed observation than by the most brilliant speculation; and in observation, concentrated systematic effort on a special thoughtfully selected problem will be of more avail than the most brilliant but disconnected work."

These few words may be taken as his scientific creed or confession of faith. Certainly his work forms a most significant commentary on its value. Born in Aberdeenshire, Scotland, in 1843, and educated at Aberdeen, he became Lord LINDSAY'S assistant at the Dun Echt Observatory; and by him was sent to Mauritius, in 1874, to observe the transit of *Venus*. Dr. GILL took advantage of this opportunity to test practically his modification of the method of determining the value of the solar parallax from observations of a minor planet, first proposed by Dr. GALLE, of Breslau. Thus his first extensive piece of work was an important contribution to the determination of this fundamental constant of astronomy.

The next was the determination of the same constant from heliometer observations of the planet *Mars* at the opposition of 1877, a work for which the Royal Astronomical Society awarded him its gold medal in 1882. The last great piece of work published by him is his determination of this same constant from observations of the minor planets, *Iris*, *Victoria*, and *Sappho*, a work resulting in a value of this quantity which is generally admitted to be the most exact known, and one which, in all probability, will suffer but slight correction from future investigations. A better example of "concentrated systematic effort on a special thoughtfully selected problem" and of its "avail" it would be hard to find.

The efforts of astronomers to arrive at the value of the solar parallax, or its equivalent, the mean distance of the Earth from the Sun, form one of the most interesting chapters in the history of astronomy. From the earliest times it has engaged the minds of men; for a knowledge of it is necessary to give us any true conception of the actual dimensions of the solar system, of the masses and distances of the planets, and, ultimately, of the fixed stars. We cannot take time to recount the many solutions that have been attempted of this "the noblest problem in astronomy," as Sir GEORGE AIRY describes it. We must content ourselves with quoting Dr. GILL'S own remark, that "Every attempt has shown some short-coming in the previous one, and the result has always been to mark a new era of progress in the science, to create a fresh interest in its pursuit, and to stimulate the invention of more refined instruments and methods."

In 1867, NEWCOMB, from a discussion of all the available data, derived the value 8''.848, corresponding to a distance of about 92,370,000 miles. This result was generally adopted by astronomers in their calculations, though no one was satisfied that it was sufficiently near the truth to make further investigation unnecessary. The question was, What method should be adopted to secure the most reliable result in the shortest time? Lord LINDSAY and Mr. GILL proposed to combine the suggestions of Dr. GALLE, of measuring the displacement of an asteroid among the stars at the time of opposition, with Sir GEORGE AIRY'S, of employing what is now known as the diurnal method of observation, and to substitute the heliometer for the ordinary equatorial and micrometer.

The fact that *Juno*, one of the nearer asteroids, came to opposition at the time when they planned to be at Mauritius to observe the transit of *Venus* in 1874, seemed to offer a favorable opportunity to test the practical value of this new method. Owing to unfortunate delays in the arrival of the expedition at Mauritius, the series of observations was only one-third as extensive as had been planned, and, in consequence, the observers themselves did not "attach high importance to the value of the parallax deduced." The *important* result of this attempt was the high degree of precision which was found to attend the heliometer measures, confirming their previous conclusion, "that it is possible by means of the heliometer to determine the place of a minor planet relative to two stars (or if within a distance of 1000'', to one star) with a probable error of less than 0''.01." This led Dr. GILL to hope that the same method might be employed in observations on *Mars* at the very favorable opposition in 1877 with results of greater precision than could be attained by any other known method.

Through the liberality of Lord LINDSAY and several other members of the Royal Astronomical Society, and with the aid of grants from the Royal Society and from the Royal Astronomical Society, Dr. GILL was enabled to take the heliometer used in the *Juno* observations, together with the necessary subsidiary instruments, to the island of Ascension to put his plan to the practical test. The method of observation was similar to that employed in the former attempt, with some modifications suggested by the experience then gained. It consisted, in brief, in observing the position of *Mars* with reference to selected stars as early after sunset in the evening and as late before sunrise in the morning as practicable, thus measuring double the parallactic displacement of the planet. The accuracy attainable in these measures is so great that it was desirable to have the positions of the comparison-stars fixed with all possible precision. To this end these stars were carefully reobserved at thirteen of the principal observatories of the world.

The final result of this admirable piece of work was to fix the value of the solar parallax at $8''.78 \pm 0''.012$. At the time, this ranked as one of the best determinations of this constant that had been made, and, as we have said, the work won for its author the gold medal of the Royal Astronomical Society. But in his memoir, Dr. GILL himself showed that the result might be subject to a possible small correction from difficulties peculiar to observations of *Mars*, and again stated with emphasis that the most promising method to insure an accurate result was by the heliometric observation of such of the minor planets as approached nearest to the Earth.

The exceptionally favorable oppositions of *Iris* in 1888, and of *Victoria* and *Sappho* in 1889, afforded an excellent opportunity to repeat the observation, and by that time, too, a number of very powerful heliometers had been constructed, several of them possessing refinements of adjustment planned by Dr. GILL himself. Having secured assurances of co-operation in the observations from a number of heliometer observers,—especially from Dr. ELKIN, of Yale, and from Dr. AUWERS, of Berlin,— Dr. GILL issued a carefully planned programme of work which made provision for "the complete determination and elimination of every preconceivable form of systematic error." This was fully carried out; concerted observations of the three asteroids were made at the Cape of Good Hope, in the southern hemisphere, and at New Haven, Göttingen, Leipzig, Bamberg, and Oxford, in the northern; the comparison-stars were carefully reobserved on the meridian-circles of the principal observatories of the world; and the whole mass of material reduced and discussed with every refinement of method known to modern astronomy.

It is difficult to form an adequate conception of the amount of labor involved in such a piece of work. Aside from the careful observations of the phenomena themselves, thousands of observations most trying to the eyes are necessary to determine with accuracy the errors of the instruments, (Dr. GILL, for example, made about fifty thousand observations, the equivalent of nine months' work at two hours a day, to determine the division-errors of the scales of his heliometer,) and when the observation material is at last all collected, the real work may be said to have just begun. To handle such an enormous mass of data, to subject it to the minute and detailed analysis necessary to eliminate all possible forms of error, to reduce it to a manageable set of normal equations, and, finally, to determine the most probable values of the quantities sought, demands not only mathematical judgment and skill of the highest order, but also patient tenacity of purpose and a tremendous capacity for work.

While the determination of the definitive positions of the comparison-stars from the meridian-circle observations was due to Dr. AUWERS, and the discussion of the results for *Iris* to Dr. ELKIN, the plan of the entire work was Dr. GILL'S. He discussed the results for *Victoria* and *Sappho*, made the final revision of the work, and is responsible for the result. His conclusion is that the value of the solar parallax from these observations is 8″.802, with a probable error of ± 0″.005, and that this may be regarded as absolutely reliable within such limits as are indicated by the value of its probable error. This means that the distance from the Earth to the Sun is known to within about fifty or sixty thousand miles. Or, to illustrate the accuracy of the result in another way, the outstanding error may be represented by the angle subtended by a foot-rule at a distance of a little over seven thousand miles.

It must not be supposed that Dr. GILL'S entire time has been devoted to investigations of the solar parallax. Although his work in this connection has been sufficient to insure him a very high rank among astronomers, it has been far from completely engrossing his attention. On his appointment as H. M. Astronomer at the Cape of Good Hope in 1879, Dr. GILL took with him the heliometer used in his observations of *Juno* and *Mars*, and, in the years 1881–83, instituted a series of observations to determine the value of the annual parallax of nine of the more interesting southern stars. In this work he had the assistance of Dr. ELKIN, who was his guest during those years. "These investigations constitute the first successful attempt made by extra-meridian observations, to determine stellar parallax in the southern hemisphere." The results for the nine stars measured are accepted generally by astronomers. This work has been, and is being, continued with the new heliometer, by Dr. GILL and other observers under his direction, the "great cosmical questions to be answered" being "not so much what is the precise parallax of this or that particular star, but (1) what are the average parallaxes of those of the first, second, third, and fourth magnitude, respectively, compared with those of lesser magnitude? (2) what connection does there subsist between the parallax of a star and the amount and direction of its proper motion? or can it be proved that there is such a connection or relation? From such data we should probably be able to determine the law of absorption of star-light in space, and be provided with the facts at present wanting for determining with more precision the amount and direction of the motion of the solar system in space." A second memoir on this subject, giving the parallaxes of thirteen additional stars, is now nearly completed.

While work in these two allied fields of research may be regarded as the more important of Dr. GILL'S personal contributions to the advancement of astronomy, we must not fail to call attention to the great services he has rendered in the past twenty-one years as Director of the Observatory at the Cape of Good Hope, and to the important enterprises he has inaugurated or been intimately associated with. Struck with the splendor of the great comet of 1882, he secured, with the aid of a local photographer, several photographs of it. The number and sharp definition of the star-images on these plates led him to suggest the use of photography for star-charting in general, and in particular for extending the Bonn Durchmusterung from — 23° to the South Pole. Without reviewing the history of the movement that led finally to the assembling of the Astrophotographic Congress and its decision to photograph the entire heavens on a uniform system, we may note that Dr. GILL took an important part in all the proceedings; and that the Cape Observatory has practically completed the series of photographs needed in the zone from — 40° to — 52° Declination. The work of measuring up these plates is now in progress under Dr. GILL's supervision and on engines built from his designs.

But before the Astrophotographic Congress met, Dr. GILL had decided to carry out his idea of a photographic Durchmusterung of the heavens south of — 23° Declination; and by the year 1889 the necessary plates had all been taken — in considerable part at his private expense. Professor KAPTEYN, of Gröningen, volunteered to undertake the labor of measuring these plates, the pressure of other work making it impossible to measure them at the Cape Observatory. Two volumes of this great work, containing the places and magnitudes of more than 316,000 stars between — 19° and — 52° Declination, have already been distributed, and the third, which will complete the work, is nearly ready.

Of the ordinary administrative duties pertaining to a position such as Dr. GILL holds, we need here say nothing more than that the building up of a great observatory (and such the one at the Cape of Good Hope has become under his direction) would of itself be a task sufficient for a life-work. When we add that in addition to all else, Dr. GILL has found time to design the instruments and methods employed in the geodetic survey of South Africa, to plan and control the field operations, and personally to superintend and take part in the measurement of several of the base-lines, we are obliged to admire his capacity for work almost as much as his ability as an observer and a mathematician.

This brief sketch, imperfect as it is, will, I think, serve to show that Dr. GILL's services to astronomy have been amply adequate to entitle him to the highest honor we can bestow upon him,— the award of the Bruce Gold Medal.

Mr. Secretary, in the absence of our medalist, I hand the award to you, to transmit to Dr. GILL, with the assurances of the heartiest wishes of this Society that his future labors may be rewarded with the distinguished success that has crowned them in the past.

March 31, 1900.

ASTRONOMICAL OBSERVATIONS IN 1899.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

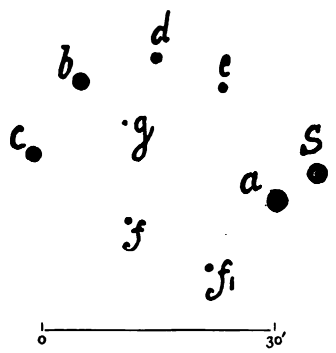
VARIABLE STARS.

*Z Cygni.**

January	5:	Z almost invisible.
February	5:	invisible.
March	30:	id.
April	17:	= e.
May	6:	a little < c.
	28:	< a. > b.
August	5:	< e.
	13:	id.
September	13:	invisible.
	24:	id.
October	25:	id.
November	20:	id.
December	3:	id.
	22:	= e.
	30:	a little < d.

S Ursæ majoris.

January	5:	S a little < e.
	13:	id.
	17:	< e. > f 1.
February	5:	= f 1.
	10:	id.
	14:	almost = g.
March	10:	< g.
	30:	almost = g.
April	2:	id.
	12:	id.
	22:	= f 1.
April	28:	> f 1. < e.
August	5:	= e.
August	13:	a little < e.
	26:	= f i.
	31:	a little < f i.
September	4:	= f.
	9:	id.
	12:	id.
	24:	= g.
October	4:	id.
	8:	< g.
	25:	id.
November	20:	= g.
December	3:	a little < f 1.
	22:	> f 1. < e.
	30:	a little < e.



a = 6.5 Mag.
b = 7.0
c = 7.2
d = 8.5
e = 9.2
f1 = 10.0
f = 10.2
g = 10.3

---

* *Vide* the sketch in the *Publications* A. S. P., No. 48, page 60.

*T Ursæ majoris.**

January 5: = e.
17: = g.
February 5: a little < g.
10: < g.
14: id.
March 10: invisible.
30: extremely faint.
April 2: id.
12: invisible.
22: id.
28: id.
August 5: = a.
13: almost = b.
26: = c.
August 31: = d.
September 4: a little < d.
9: id.
12: $\left\{\begin{array}{l} < \text{d.} \\ > \text{e.} \end{array}\right.$
24: $\left\{\begin{array}{l} < \text{e.} \\ > \text{f.} \end{array}\right.$
October 8: = f.
25: < g.
November 20: invisible.
December 3: id.
22: extremely faint.
30: invisible.

W Pegasi.†

January 5: W < g.
February 5: id.
10: faint.
May 6: a little > f.
August 5: $\left\{\begin{array}{l} < \text{b.} \\ > \text{c.} \end{array}\right.$
13: a little > c.
14: $\left\{\begin{array}{l} > \text{c.} \\ < \text{b.} \end{array}\right.$
26: a little < c.
31: id.
September 4: < c.
September 9: $\left\{\begin{array}{l} < \text{c.} \\ > \text{d.} \end{array}\right.$
12: a little > d.
13: id.
24: a little < e.
October 4: a little > f.
7: id.
8: id.
25: = g.
November 9: id.
20: < g.
December 22: invisible.
31: id.

The Star BD, 20°, 1083.

January 6: $\left\{\begin{array}{l} \text{Star} < \text{b.} \\ \quad\;\; > \text{c.} \end{array}\right.$
February 6: id.
10: = c.
14: id.
April 2: $\left\{\begin{array}{l} \text{almost} = \text{c.} \\ \text{not} > \text{c.} \end{array}\right.$
December 3: = b.
31: $\left\{\begin{array}{l} = \text{c.} \\ < \text{b.} \end{array}\right.$

The variations were in this year only between the limits: 8.2 and 8.5 mag.

---

* *Vide* the sketch in the *Publications* A. S. P., No. 22, page 63.
† *Vide* the sketch in the *Publications* A. S. P., No. 60, page 23.

SHOOTING STARS.

No.	Time.	Beginning.	End.	Mag.	Note.
	h m s	° °	° °		
1	Aug. 9, 10 7 0 P.M.	216 + 38	224 + 22	2	
2	13 0	292 + 65	259 + 58	2	Train.
3	14 0	201 + 61	191 + 60	4	
4	16 30	129 + 68	153 + 62	3	
5	17 0	34 + 57	120 + 64	3	Light undulations.
6	24 30	256 + 12	257 − 1	3	
7	24 40	355 + 13	351 + 10	3	
8	28 30	317 + 39	297 + 25	3	
9	38 30	193 + 55	180 + 54	3	
10	42 45	11 + 76	346 + 81	2	Train.
11	46 30	353 + 45	353 + 33	1	Train.
12	55 30	277 + 68	252 + 55	2	
13	58 15	3 + 39	347 + 31	3	
14	11 0 0	297 + 77	297 + 57	3	
15	2 0	357 + 19	350 + 14	2	
16	2 5	305 − 6	302 − 11	2	
17	3 0	191 + 65	198 + 50	3	
18	6 30	309 + 46	330 + 62	2	
19	10 0	334 + 48	324 + 44	2	
20	14 0	242 + 21	245 + 10	2	
21	16 30	200 + 75	217 + 57	1	Train.
22	19 0	175 + 51	187 + 38	1	
23	23 45	252 + 25	247 + 7	1	Train.
24	26 50	332 + 36	317 + 30	3	
25	28 30	289 + 8	285 − 5	2	
26	32 0	23 + 23	18 + 7	1	Train.
27	43 0	34 + 56	17 + 54	2	Train.
28	49 0	275 + 40	258 + 18	1	Train.
29	49 5	300 + 16	294 + 4	1	Train.
30	51 30	259 + 30	259 + 13	1	Train.
31	51 45	326 + 36	312 + 17	♃	Yellow train.
32	52 30	270 + 50	280 + 41	2	
33	56 15	295 + 10	288 + 23	1	
34	Aug. 10, 12 0 15 A.M.	236 + 70	217 + 53	2	Train.
35	Aug. 11, 10 20 0 P.M.	144 + 55	160 + 46	2	
36	22 30	170 + 53	183 + 45	2	
37	31 0	253 + 32	250 + 18	2	
38	35 0	318 + 56	296 + 46	2	Train.
39	37 0	287 + 50	277 + 34	1	Train.
40	42 0	342 + 34	333 + 19	2	Train.
41	44 0	350 + 62	310 + 66	1	Train.
42	46 0	360 + 89	232 + 76	1	Train.
43	49 0	145 + 75	183 + 62	2	Train.
44	57 30	339 + 13	352 + 18	2	Slow.
45	11 2 30	339 + 13	15 + 8	♃	Nebulous.

No.	Time.	Beginning.	End.	Mag.	Note.
	h m s	° °	° °		
46	Aug. 12, 10 5 45	339 + 13	77 + 61	1	
47	9 0	215 + 80	218 + 64	2	Train.
48	17 45	327 + 38	312 + 27	3	Train.
49	20 45	330 + 17	332 + 6	3	Fast.
50	23 45	120 + 73	162 + 70	3	
51	26 0	129 + 61	163 + 52	2	Train.
52	27 30	129 + 61	324 + 37	3	
53	32 0	312 + 12	316 + 5	1	
54	34 0	173 + 65	192 + 53	1	Train.
55	35 0	348 + 43	360 + 28	2	
56	36 30	317 + 45	317 + 37	3	
57	51 30	304 + 48	302 + 35	3	
58	52 10	338 + 8	333 − 1	2	
59	55 0	38 + 46	28 + 35	1	Train.
60	56 0	179 + 52	184 + 45	1	
61	11 0 40	358 + 21	350 + 12	2	Train.
62	1 30	228 + 43	224 + 28	2	Train.
63	1 35	233 + 42	224 + 24	2	
64	2 30	293 + 12	283 + 5	2	
65	2 45	271 + 33	258 + 26	1	Train.
66	5 40	271 + 33	295 − 21	1	
67	7 15	355 + 3	350 − 8	1	Train.
68	9 30	224 + 39	222 + 25	3	Train.
69	12 20	327 + 17	318 + 4	4	
70	14 30	170 + 78	181 + 62	3	Train.
71	15 10	290 + 8	284 − 3	1	Train.
72	17 0	91 + 41	92 + 34	1	Train, fast.
73	27 30	252 + 28	247 + 11	3	
74	32 30	260 + 62	210 + 52	3	
75	35 0	122 + 59	140 + 53	1	
76	35 30	122 + 59	311 + 23	1	
77	43 30	335 + 35	352 + 44	2	Streak, slow.
78	43 40	267 + 30	277 + 6	1	Train.
79	46 45	197 + 47	200 + 38	1	Train.
80	49 0	265 + 7	265 − 6	1	Train.
81	51 0	330 + 53	330 + 38	♀	Train.
82	57 10	10 + 41	358 + 33	2	Streak.
83	Aug. 13, 12 1 0 A.M.	315 + 27	302 + 15	1	Train.

No. 8. This meteor was also observed at Copenhagen: 232° + 38° —> 226° + 21° (2).

No. 13. Was also observed at Copenhagen: 216° + 47° —> 223° + 32° (2).

No. 21. End point observed at Copenhagen: 208° + 32° (3).

No. 81. Was observed at Copenhagen: 237° + 33° —> 230° + 17° (2).

The four meteors named have given the following results:—

No.	Beginning.			End.			Real Length of the Path.	Observer.
	h	λ	ϕ	h	λ	ϕ	β	
		° ′	° ′		° ′	° ′		
8	116	1 43	55 43	87	2 15	55 31	50	TORVALD KÖHL. OTTO ASMUSSEN.
13	76	1 13	56 3	66	1 31	55 51	31	TORVALD KÖHL. OTTO ASMUSSEN.
21	...	...	...	109	3 40	56 34	..	TORVALD KÖHL. OTTO ASMUSSEN.
81	92	2 11	55 57	42	2 16	55 50	51	TORVALD KÖHL. OTTO ASMUSSEN.

⁂ h and β are expressed in kilometers; λ is W. long. from Copenhagen; ϕ is N. lat.; h is the altitude of the meteor above the Earth's surface.

Odder is situated in 2° 25′ W. long. from Copenhagen and 55° 58′ N. lat.

Only a few *Leonids* were seen in the period, November 13–16. The following meteors were observed here:—

No.	Time.					Beginning.	End.	Mag.	Note.
		h	m	s		° °	° °		
1	Nov. 15,	5	14	0	A.M.	156 + 27	170 + 52	♀	Train, yellow.
2			33	0		172 + 5	176 − 1	2	
3			39	30		163 + 27	178 + 30	4	Fast.
4			41	0		156 − 8	170 − 13	1	Slow.
5			45	30		175 + 45	206 + 58	1	Train, fast.
6			50	15		160 + 15	166 + 4	3	
7			55	40		170 + 13	170 + 26	4	
8			59	0		120 + 34	128 + 12	1	
9		6	0	0		139 + 27	124 + 35	2	
10			2	0		152 + 50	153 + 71	1	
11			4	45		185 − 5	187 − 8	1	
12			5	0		206 + 25	219 + 20	2	
13			7	0		103 − 13	99 − 14	4	
14			9	15		172 + 17	177 + 17	4	
15			10	30		135 + 3	129 − 7	2	
16			14	0		184 + 1	191 − 7	3	
17			16	50		190 + 28	203 + 26	1	Train, fast.
18			19	10		142 + 27	135 + 34	2	
19			28	0		160 + 25	175 + 29	3	
20	Nov. 16,	5	32	20		128 + 23	113 + 20	2	Train.
21			46	10		181 + 12	189 + 9	♀	Train, yellow.
22			48	50		157 + 27	166 + 32	2	
23			50	50		165 + 8	172 + 1	3	
24		6	2	30		144 + 7	142 − 4	♀	Train, yellow.

On the 30th and 31st of July the author made a public trial of FOUCAULT'S pendulum experiment in the Museum of Art of the Danish State at Copenhagen. The pendulum had a length of 17 meters, and weighed 35 kilogrammes. After an hour had elapsed the pendulum had just passed the twelfth degree of the circle accordant to the calculated deviation.

VISUAL OBSERVATIONS OF THE MOON AND PLANETS, MADE AT HARVARD COLLEGE OBSERVATORY.*

By Edward S. Holden.

The volumes of the Harvard Observatory *Annals* are printed with a commendable promptness that adds greatly to their usefulness. Most of them deal with technical matters of no great immediate general interest. The two volumes noticed contain several chapters, however, on the changes observed in the surface of the Moon, on the planets, etc., that are especially interesting to all intelligent people, and for this reason, it is here attempted to give some account of their contents. As many of the results attained are novel, it is, first of all, sought to present them with sufficient fullness. This is not the place for a discussion as to the evidence upon which they rest.

Volume XXXII of the *Annals* contains a chapter upon the surface conditions and the rotation of the planet *Mercury*, the diameter and atmosphere of *Venus*, and the surfaces of *Jupiter*, *Saturn*, *Uranus*, and *Neptune*. The discussion of the observations of *Mars* is reserved for another volume. The observations of *Mercury* are illustrated by sixteen sketches by two observers (W. H. Pickering and Douglas) of the excessively faint surface markings. Mr. Pickering's conclusions from these drawings are that no rotation of the markings was noticeable between July 14, and August 5, 1892, a period of twenty-two days, or one quarter of the period of revolution of the planet in its orbit, and that the period of rotation of the planet on its axis and revolution in its orbit must coincide, as was announced by Schiaparelli in 1879. It is, in fact, not unlikely that the two

---

*Annals of the Astronomical Observatory of Harvard College. Edward C. Pickering, Director. Vol. XXXII, Part II. Visual Observations of the Moon and Planets, by William H. Pickering, Assistant Professor of Astronomy in the Observatory, Cambridge, 1900, 4to, and *ibid.* Vol. XXXIII. Miscellaneous researches made during the years 1894-99. Cambridge, 1900, 4to.

periods do coincide, but the observations here given present little evidence to prove it. The drawings of the two observers, P. and D., differ on July 22d at 8^h, agree very well at 10^h, differ widely on July 23d at 6^h, agree fairly on July 23d at 9^h. But the drawings last mentioned should agree with the pair made at 10^h of the day previous to prove the point at issue, whereas there is little, if any, resemblance; and there is no agreement at all in the extremes of the series July 14th and August 5th. The observations in question are excessively difficult to make, but those that have been secured are not, it would seem, adequate. Mr. PICKERING concludes that the atmosphere of this planet is very rare, and that the hemisphere turned towards the Sun is very likely incandescent, while the temperature of the central regions of its opposite hemisphere is much lower than that of our Arctic regions. A curious distribution of matter would thus take place on the surface, through a process of fractional distillation. The hemisphere that is perpetually illuminated by the Sun would be composed of substances of high boiling points, while the other hemisphere would be composed only of those of very low boiling points. It is not likely, we may add, that a planet subject to such conditions can sustain human life.

The diameter of the planet *Venus* was determined to be 7,662 miles. In its size, as well as in certain other respects, it is not unlike our Earth. Measures of the horizontal refraction of the atmosphere of *Venus* give 93′, which is much greater than previous results. If, as is probable, the surface of *Venus* seen by us, is no more than the outer layers of its clouds, it follows that at the planet's real surface its atmosphere is many times denser than our own. We may add here, that there is no proof that *Venus* is unfit for human habitation.

"The most important discovery relating to *Jupiter*," Mr. PICKERING says, "was in regard to the nature of the material forming its belts. As had been previously surmised, they were found to lie above the white, dense, cloudy surface of the planet; but what was perhaps unexpected, was the fact that the appearance was not due to large dense masses of cloud, but to numerous very minute, isolated cloudlets." A very good photograph of *Jupiter*, and an excellent photograph of *Saturn*, are reproduced in the plates.

The diameter of the planet *Neptune* was determined to be 31,000 miles, and its disk was found to be decidedly darker at the edge than at the center, thus proving the existence of a deep atmosphere. *Jupiter*, *Saturn*, *Uranus*, and *Neptune* are, it may be added, alike in this respect. All of them have extensive atmospheres, but little is known of the constitution of their envelopes, and next to nothing of the condition of their solid or liquid nuclei. It is likely that all of them are at a high temperature.

SWIFT'S comet of 1892 was the subject of investigation by photography and otherwise. Some of the photographs are reproduced in the volume, and they are extremely interesting. Those of the inner portions of the tail seem to show that the comet was rotating on an axis passing longitudinally from the head through the tail in a period of about four days. Mr. PICKERING points out that there is an *a priori* reason for such a rotation. "In the light of the connection between sun-spots and terrestrial electric disturbances, it may be assumed that the Sun can be looked upon as an enormous electro-magnet, surrounded by an equatorial electric current. If now, the tail of a comet is due to electrically charged gaseous matter receding from the nucleus, we shall have a series of electric currents radiating from the nucleus like spokes upon the hub of a wheel, and bending backwards to form the tail. If the Sun and comet are electrified, as we have supposed, the jets and envelopes of the comet, carrying with them the tail, must rotate as we have described."

As the earth has a gaseous envelope, like a comet, and as it is subject to electric action from the Sun, the question arises whether something analogous to a comet's tail is not to be found on the Earth. Mr. PICKERING finds the analogy in the high auroras. "All the observations of high auroras are located along a line such as would be cut upon the surface of the Earth by a cylindrical tail 7,200 miles in diameter, whose axis passed through the center of the Earth and pointed directly away from the Sun." In diameter, length, direction, and time of formation, the aurora is shown to resemble the tail of a comet, and it appears likely that the secular auroral period has its analogue in the world of comets. Mr. PICKERING'S prediction is, that if a comet comes in view of the Earth during a year of great sun-spot activity, it is more likely to have a large and fine tail than if it arrives during a year of slight activity. Such a theory as this might, it would seem, be tested by the appearances of ENCKE'S periodic comet.

The following paragraph is quoted as a brief explanation of the phenomena of comets expressed in a simple form :—

"The head of a comet seems therefore to be merely a meteor-swarm containing so much gaseous material that when electrified by its approach to the Sun, it will be rendered luminous. When the gases, by successive discharge and loss into space, have become too rare to be rendered visible in this manner, the object, if discovered, is known simply as a meteor-swarm. Each meteor in the comet's head, when remote from the Sun, is surrounded by its own individual atmosphere of hydrocarbons, etc., in a solid condition. When this atmosphere is sufficiently warmed by the Sun's rays to evaporate, it becomes sufficiently electrified to partially overcome the slight force of gravity of the meteors, and a portion of it escapes and unites with that of other meteors to form the tail. Thus, if the meteors and their atmospheres are sufficiently widely separated from each other, the comet may be brilliant and yet transparent at the same time."

No space remains to speak in detail of other interesting researches in these volumes. Long-continued observations on the Moon prove the existence of changes on its surface, of vegetation, of a slight atmosphere, according to Mr. PICKERING. As many of his conclusions are in the nature of discoveries, they will not pass unchallenged, and it is not difficult to point out paragraphs where more evidence is very desirable. At the same time, it is only just to say that the treatment of all the topics in the volume is suggestive, and thus very valuable, though it is often inconclusive, being based on too slight and easily accepted foundations. Volume XXXIII is devoted to miscellaneous researches on the brightness of certain asteroids, on the Gegenschein and Zodiacal Light (by Professor SEARLE), on Variable Stars, Nebulæ, Comets, Satellites, etc. Taken together, the volumes contain results of long-continued and faithful work, intelligently directed.

THE CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION, MAY 28, 1900.

By CHARLES BURCKHALTER.

The preparations for the expedition from this Observatory to observe the eclipse of May 28th next, at the expense of one of our members,—Mr. JOHN DOLBEER, of San Francisco,—are nearly completed. The Pierson eclipse telescope, with the Pardee lens attached, making two telescopes of four-inch aperture and fifteen feet focal length, is ready for shipment, and will be forwarded in a few days, to insure arrival in ample time.

The Southern Pacific Company and its connections, by the kindness of General Traffic Manager WILLIAM SPROULE, has granted less than half-rate for transportation of instruments. The station will be at or near Union Point, Georgia, and a leading man of the place, WILLIAM HART, Esq., has already placed me under obligations for valuable information and offers of help.

As the geographical position of the village is uncertain by as much as three miles or more, it will be necessary to observe for position — especially for latitude — before "establishing" the station. I expect to start in time to make the preliminary observations and be ready for actual installation of instruments by May 1st, which will give me ample but not unnecessary time for complete preparation. I have already received offers of volunteer assistance from Mr. HART and others, and I feel confident that I shall be in good hands, and it will be a real comfort, after the experiences of the last two expeditions, to be in a country where it will not be necessary to talk either through an interpreter or with my hands and feet.

In working out the controlling diaphragms, the exposure times are computed for each minute from 16′ to 30′ (counting from Sun's center), and thereafter for each two minutes, intermediate places giving intermediate times.

In the partial table below, the exposures are given for each minute from 16′ to 20′; then at four-minute intervals, from 20′ to 40′, and thereafter at ten-minute intervals, except at 75′ and 76′, where numbers 1, 3, 7, and 9 end. It will be observed that numbers 2 and 8 apparently stop at 50′ and 60′. Both of these, however, end at 95′; but, as they are experimental, they are not given in full.

Number 4 is Secretary ZIEL's ideal exposure, after a study of the India negatives of the Pierson expedition. This curve I expect to be one of the very best, especially as I intend to bring him this plate and others for expert development. Number 8 is my own ideal, and may be said to be a "middle-of-the-road" exposure out to 64′.

The exposures will be made in pairs, five for each telescope, the times of each pair being identical, as the exposures begin and end simultaneously by electrical apparatus.

I shall use Cramer crown plates, and have entire confidence that the times indicated in the table cannot be far wrong, and that at least one plate will be nearly perfectly exposed. I am especially confident that the time given at the Moon's edge is too much, rather than too little, and if I find at the end of the programme that I can make an additional exposure of two seconds, I have a diaphragm prepared that will give only $0^{s}.01$ at the Moon's edge in a two seconds exposure.

The exposures given below can be made with great exactness, probably within two or three per cent. This is especially true for the extreme inner corona. For example, if number 6 should receive a total exposure of only 8^{s} instead of 10^{s}, as proposed, the exposure at 16′ would be only $0^{s}.04$ instead of $0^{s}.05$. As the exposures are made by moving a lever to the right and left, engaging electrical contacts, they can be made with nearly the same precision as recording the transit of a star on the chronograph.

PROPOSED EXPOSURES, MAY 28, 1900.

Order of Exposure No.	1	2	3	4	5	6	7	8	9	10
	s	s	s	s	s	s	s	s	s	s
Exposure at Moon's Limb	0.02	0.04	0.10	0.06	10.00	0.05	0.08	0.05	0.12	0.06
Total Exposure	4.00	4.00	8.00	8.00	10.00	10.00	8.00	8.00	6.00	6.00
Exposure Counting from	s	s	s	s	s	s	s	s	s	s
Center of Sun ... at 16′	0.02	0.04	0.10	0.06	10.00	0.05	0.08	0.05	0.12	0.06
17	.04	.06	.16	.09		.12	.11	.10	.14	.08
18	.08	.10	.24	.14		.18	.18	.15	.18	.12
19	.12	.16	.36	.20		.29	.26	.22	.23	.18
20	.18	.22	.50	.27		.41	.35	.30	.30	.25
24	.42	.56	1.70	.55	(Not controlled.)	1.00	.86	.73	.76	.62
28	.78	1.06	3.22	.94		1.72	1.58	1.40	1.72	1.16
32	1.21	1.70	4.56	1.48		2.20	2.42	2.18	3.14	1.96
36	1.62	2.31	5.34	2.10		2.60	3.16	3.00	4.00	2.80
40	2.00	2.85	5.90	2.85		3.00	3.83	4.00	4.50	3.42
50	2.83	3.65	6.73	4.30		4.00	5.08	6.38	5.17	4.41
60	3.52	...	7.36	5.40		5.00	6.25	7.50	5.56	5.02
70	3.96	...	7.84	6.20		6.00	7.41	...	5.87	5.50
75	3.99	...	8.00	...		...	8 0	...	6.00	...
76	4.00	...	...	...		...	...	...	...	...
80	...	...	...	6.90		7.00	...	...	...	5.84
90	...	...	...	7.50		8.00	...	...	...	6.00
95	...	...	...	...		...	...	...	...	...
100	...	...	...	8.00		9.00	...	...	...	...
110	...	...	...	...	10.00	10.00	...	...	...	...

CHABOT OBSERVATORY, Oakland, Cal., March 10, 1900.

SOME COMPUTATIONS RELATIVE TO THE SOLAR ECLIPSE OF MAY 28, 1900.

By S. C. Phipps.

While studying the theory of eclipses in the course in advanced practical astronomy under Dr. **Townley**, some computations were made for the eclipse of May 28, 1900.

Starting with the data given in the *American Ephemeris*, the elements of the eclipse, rising and setting limits, maximum in the horizon, northern and southern limits, curve of central eclipse, and northern and southern limits of the total eclipse, were computed according to the methods given in **Chauvenet's** "Spherical and Practical Astronomy." In most cases the results agree exactly with those printed in the *Ephemeris*, the greatest difference being one tenth of a minute in some of the latitudes and longitudes. About three fourths of the above work was also computed by Mr. B. A. **Baird**.

The circumstances of the eclipse for Mr. **Burckhalter's** station near Union Point, Georgia, (latitude 33° 36′ north, and longitude 83° 3′.2 west,) were computed, giving the following results:—

	Local Mean Time (Ast.)			
Beginning of eclipse......	May 27th,	19^h	00^m	57^s
End of eclipse		21	26	34
Duration of eclipse		2	25	37
Beginning of total eclipse .		20	8	16
End of total eclipse......		20	9	40
Duration of total eclipse..			1	24

	First Contact.	Fourth Contact.
Position-angle,	256° 32.′2	76° 33.′4

The position-angle is measured from the north point of the Sun's image toward the east.

The eclipse will be seen as a partial one in California, and in the neighborhood of San Francisco the eclipse will begin before sunrise. I have computed the circumstances of the eclipse for the Student's Observatory, Berkeley, (latitude 37° 52′.4 north, longitude 122° 15′.5 west,) and for the Davidson Observatory, San Francisco, (latitude 37° 47′.5 north, longitude 122° 25′ 7 west,) giving the following results:—

Maximum of eclipse:
Berkeley, May 28th, $5^h\ 37^m\ 35^s$ A. M., P. S. T.
San Francisco, May 28th, $5^h\ 37^m\ 31^s$ A. M., P. S. T.

End of eclipse:
Berkeley, May 28th, $6^h\ 27^m\ 40^s$ A. M., P. S. T.
San Francisco, May 28th, $6^h\ 27^m\ 36^s$ A. M., P. S. T.

Greatest obscuration:
Berkeley, 0.5104.
San Francisco, 0.5107.

Position-angle of fourth contact:
Berkeley, 107° 46′.3
San Francisco, 107° 46′.1.

The amount of obscuration indicates that the Moon will cover a little more than half the Sun's diameter.

Sttdents' Observatory,
University of California, March 23, 1900.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1900.

By Malcolm McNeill.

May.

Eclipse.— There will be a total eclipse of the Sun on the morning of May 28th. The total eclipse begins at sunrise in the Pacific off the coast of Mexico, and the line of totality crosses the United States from Louisiana to Virginia; thence crossing the Atlantic to Spain; thence through Spain and North Africa to Egypt, where it ends at sunset. Unfortunately, the duration of totality is short — less than two minutes from any land station where it can be seen. It will be visible as a partial eclipse throughout the United States.

Mercury is a morning star until May 29th, when it passes superior conjunction and becomes an evening star, but is not far enough away from the Sun to be easily visible at any time during the month.

Venus having passed greatest east elongation in April, has now begun to approach the Sun, and the distance lessens about 5° during the month; the interval also between sunset and the setting of the planet shortens from about four to about three hours. It moves westward among the stars about 26° during the month, to a point in *Gemini* a few degrees south of *Castor and Pollux*. It reaches greatest brilliancy about the end of the month, and throughout the month will be bright enough to be seen in full daylight in clear weather.

Mars is increasing its apparent distance from the Sun, and by the end of the month rises about an hour and a half before sunrise, so that it may be seen in the early morning twilight under good weather conditions; but it will not be at all conspicuous.

Jupiter rises earlier, before sunset, toward the close of the month, and is getting into good position for evening observation. It is in opposition with the Sun on May 27th. It moves westward about 4° in the constellation *Scorpio*, and on May 31st is in almost the same position it held on January 26th.

Saturn rises at about 9 P.M on May 31st. It moves westward about 2° in *Sagittarius* during the month, and at the end of the month it is in about the same position it occupied at the end of February. It is following in its retrograde motion even more closely than did *Jupiter* the path it marked out during its forward (or eastward) motion. Sometimes the retrograde motion of these planets is along a path which makes quite a loop with the forward motion.

Uranus is still near *Jupiter*, but rather farther away than during April. By the end of the month it is 5° east and 1° 38′ south of *Jupiter*. It moves a little more than 1° westward during the month in the constellation *Scorpio*.

Neptune is still in the extreme eastern part of *Taurus*, near *Gemini*, and moves about 1° eastward during the month.

JUNE.

Eclipse.— There will be a partial eclipse of the Moon on the night of June 12–13th, visible throughout the United States. The fraction of the Moon's diameter which will be obscured is only 0.001, so that it is a very partial eclipse indeed, and will scarcely be detected without careful instrumental measurement. Naked-eye observations will hardly be able to detect anything unusual about the Moon. However, the eclipse is perhaps interesting from the fact that its occurrence is all that saves the year 1900 from having the minimum possible number of eclipses

— two of the Sun (there will be another eclipse of the Sun in November), as happened in 1886, and will happen again in 1904.

The Sun is at its solstice, and summer begins June 21st, 1 P.M., P. S. T.

Mercury is an evening star throughout the month, and after the first week of the month remains above the horizon an hour or more after sunset. At the end of the month the interval is more than an hour and a half. It is, therefore, in very good position for evening observation. On June 13th it passes only 3′ south of the third magnitude star ϵ *Geminorum*. The time of nearest approach occurs during daylight in this country, and the motion of the planet will cause the apparent distance to be about equal to the Moon's diameter by the time the stars become visible in the evening.

Venus is an evening star, but is rapidly approaching the Sun, so that the interval between sunset and the setting of the planet shortens from three hours, on June 1st, to about half an hour, on June 30th. It moves eastward about 4° among the stars until June 15th, and then moves westward about the same amount, but all the time moving southward, so that it does not retrace its course by several degrees.

Mars rises an hour earlier than during May, and moves 22° east and 6° north through *Aries* into *Taurus*. Towards the end of the month it is about 5° south of the *Pleiades*, and will be an easy object to see, although not conspicuous.

Jupiter is well up at sunset, and remains above the horizon until nearly morning. It moves 3° westward and a little north in the constellation *Scorpio*, and at the end of the month is less than half a degree east and south of β *Scorpii*.

Saturn is above the horizon practically the entire night, and comes to opposition with the Sun on June 23d. It moves about 2° westward in *Sagittarius*, and is just north of the Dipper handle in that constellation. There is a close conjunction of *Saturn* and the Moon on the evening of June 13th, close enough for an occultation in some parts of the world. As seen in the telescope, the apparent breadth of the rings is just about as it was during the opposition of 1899, very near the maximum.

Uranus is still in the neighborhood of *Jupiter*, a little farther away than during May, the average distance being about 6° east and 2° south.

Neptune is moving slowly eastward in the extreme eastern part of *Taurus*.

MAY-JUNE, 1900.

PHASES OF THE MOON, P. S. T.

			H. M.
First Quarter,	May	6,	5 39 A.M.
Full Moon,	May	14,	7 37
Last Quarter,	May	21,	12 31 P.M.
New Moon,	May	28,	6 50 A.M.
First Quarter,	June	4,	10 59 P.M.
Full Moon,	June	12,	7 38
Last Quarter,	June	19,	4 57
New Moon,	June	26,	5 27

THE SUN.

	R. A.	Declination.	Rises.	Transits.	Sets.
1900	H. M.	° ′	H. M.	H. M.	H. M.
May 1,	2 33	+ 15 1	5 5 A.M.	11 57 A.M.	6 49 P.M.
11,	3 11	+ 17 50	4 53	11 56	6 59
21,	3 51	+ 20 9	4 44	11 56	7 8
June 1,	4 36	+ 22 2	4 39	11 58	7 17
11,	5 17	+ 23 5	4 36	11 59	7 19
21,	5 58	+ 23 27	4 36	12 1 P.M.	7 26.
July 1,	6 40	+ 23 8	4 40	12 4	7 28

MERCURY.

May 1,	1 1	+ 3 25	4 14 A.M.	10 25 A.M.	4 36 P.M.
11,	1 58	+ 9 36	4 10	10 43	5 16
21,	3 10	+ 16 44	4 17	11 15	6 13
June 1,	4 47	+ 23 20	4 45	12 9 P.M.	7 33
11,	6 18	+ 25 20	5 27	1 1	8 35
21,	7 35	+ 23 27	6 13	1 38	9 3
July 1,	8 30	+ 19 31	6 44	1 53	9 2

VENUS.

May 1,	5 43	+ 26 51	7 26 A.M.	3 7 P.M.	10 48 P.M.
11,	6 23	+ 26 53	7 27	3 8	10 49
21,	6 58	+ 26 6	7 27	3 4	10 41
June 1,	7 28	+ 24 33	7 19	2 49	10 19
11,	7 42	+ 22 48	7 2	2 24	9 46
21,	7 42	+ 20 59	6 29	1 44	8 59
July 1,	7 25	+ 19 18	5 40	12 48	7 56

MARS.

May 1,	1 8	+ 6 17	4 11 A.M.	10 32 A.M.	4 53 P.M.
11,	1 36	+ 9 12	3 49	10 21	4 53
21,	2 4	+ 11 55	3 29	10 10	4 51
June 1,	2 36	+ 14 41	3 7	9 58	4 49
11,	3 5	+ 16 56	2 48	9 47	4 46
21,	3 34	+ 18 53	2 30	9 37	4 44
July 1,	4 4	+ 20 32	2 14	9 27	4 40

JUPITER.

May 1,	16 30	− 20 55	9 11 P.M.	1 56 A.M.	6 41 A.M.
June 1,	16 15	− 20 21	6 47	11 34 P.M.	4 21
July 1,	16 1	− 19 49	4 33	9 23	2 13

SATURN.

May 1,	18 21	− 22 20	11 7 P.M.	3 46 A.M.	8 25 A.M.
June 1,	18 14	− 22 24	8 59	1 38	6 17
July 1,	18 5	− 22 28	6 48	11 27 P.M.	4 6

URANUS.

May 1,	16 41	− 22 9	9 26 P.M.	2 6 A.M.	6 46 A.M.
June 1,	16 36	− 21 59	7 14	11 55 P.M.	4 36
July 1,	16 31	− 21 49	5 10	9 52	2 34

NEPTUNE.

May 1,	5 39	+ 22 9	7 46 A.M.	3 6 P.M.	10 26 P. M.
June 1,	5 43	+ 22 12	5 45	1 5	8 25
July 1,	5 48	+ 22 14	3 52	11 12 A.M.	6 32

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope to May 27th, then off right.)

		H. M.			H. M.
I, D,	May 5,	8 27 P.M.	III, R,	June 1,	12 52 A.M.
I, D,	8,	12 41 A.M.	I, R,	1,	9 28 P.M.
I, D,	9,	7 9 P.M.	II, R,	6,	10 32
I, D,	15,	2 34 A.M.	I, R,	8,	11 22
I, D,	16,	9 3 P.M.	I, R,	10,	5 50
II, D,	20,	1 37 A.M.	II, R,	14,	1 9 A.M.
I, D,	21,	4 28	I, R,	16,	1 16
I, D,	24,	12 57	I, R,	24,	9 39 P.M.
III, D,	24,	7 8 P.M.			
I, D,	25,	5 25			
II, D,	27,	4 13 A.M.			
II, R,	30,	7 56 P.M.			
I, R,	31,	2 59 A.M.			

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

USE OF THE CROSSLEY REFLECTOR FOR PHOTOGRAPHIC MEASUREMENTS OF POSITION.

Although the observation of asteroids is not intended to be a regular part of the work of the Lick Observatory, a good many observations of these bodies have been made here during the past year. All the Watson asteroids have been observed for the National Academy of Sciences, and in the course of this work a number of new asteroids have been discovered and regularly observed.

It sometimes happens that an asteroid cannot be found readily with visual or with small photographic telescopes. It may be situated in the Milky Way, where the number of stars is confusing, or it may be faint or moving very slowly. If found, there may be no catalogue-stars near enough to it for purposes of comparison.

In such cases the Crossley reflector has furnished a convenient means for both finding the asteroid and determining its position. The method of observation is as follows: The field having been identified by means of a DM. chart, an exposure of half an hour is given to the photographic plate, in the usual manner. The slide is then closed, the guiding eye-piece of the double-slide plate-holder is slipped along two or three hundredths of an inch and again clamped, and the guiding-star is brought to the new position of the cross-wires. Another exposure of (say) two minutes is then given, the times of beginning and end being accurately noted. Finally, the slide is partly drawn, the driving-clock stopped, and stars are allowed to trail over the lower third of the plate for several minutes.

On the resulting negative, all the star-images are double. The stronger images serve for purposes of identification, and the weaker images for exact measurement. The diameter of the smallest star-discs should not exceed 1″.5 or 2″.0. The corresponding images of the asteroid are respectively a trail, and an image which is not distinguishable from a disc, and which, in the subsequent measurement of the plate, is referred to the short-exposure images of the stars. The trails serve for the accurate orientation of the plate.

---

* Lick Astronomical Department of the University of California.

On a photograph of the asteroid (439) *Ohio*, made on the night of December 27, 1899, and measured by Mr. CODDINGTON, there are eleven catalogue-stars. The mean position of the asteroid, at the mean time of exposure, $13^h\ 10^m\ 35^s$ P. S. T., is R. A. = $7^h\ 27^m\ 42^s.221$; Decl. = − 6° 9′ 26″.79.

Comparison of the mean with the individual measures gives the following residuals (Mean − Obs.):

Comparison-Star.	Residual, R. A.	Residual, Decl.
DM. − 5°2165	$-0^s.068$	−0″.56
− 6 2167	−0 .054	+0 .73
− 6 2162	−0 .030	+0 .68
− 6 2184	+0 .056	+0 .56
− 6 2166	+0 .064	−0 .97
− 6 2153	+0 .039	−0 .27
− 6 2156	+0 .003	+0 .44
− 6 2158	−0 .056	−0 .07
− 6 2146	+0 .025	+0 .31
− 6 2150	−0 .038	+0 .04
− 6 2185	−0 .051	−0 .90

The probable error of the mean is, therefore, in R. A. ± $0^s.010$; in Decl. ± 0″.12. It will be seen that this result is comparable with the best measurement by visual methods,

J. E. K.

THE CROCKER–LICK OBSERVATORY ECLIPSE EXPEDITION.

By the generosity of Mr. WILLIAM H. CROCKER, of San Francisco, the Lick Observatory will be able to send a party to Georgia, to observe the total solar eclipse of May 28th. Only two observers, Messrs. W. W. CAMPBELL and C. D. PERRINE, will be sent out from the Observatory; but several European astronomers have expressed a desire to join the party, and similar requests have also been received from astronomers connected with American colleges which do not intend to send out expeditions of their own.

I take this opportunity to acknowledge the indebtedness of the Lick Observatory to Mr. CROCKER for his generous assistance. It is especially gratifying to the members of the Observatory staff that this practical token of appreciation and confidence comes from a life member of the Astronomical Society of the Pacific, and a prominent citizen of our own State.

The instrumental equipment of the expedition will be quite complete. The principal instrument for photographing the corona will be the five-inch telescope of forty feet focal length, used by the Lick Observatory parties in South America and India. For photographing the corona on a smaller scale there will be several cameras of from five to six inches aperture and others of smaller size. One slit spectrograph, and two objective spectrographs, arranged to give a continuous record of the changing spectrum at the beginning and end of totality, are also included in the equipment. Observations of contacts will be made.

Any observers having experience in astronomical or physical work, who wish to join the party at their own expense, like the gentlemen referred to farther above, are invited to communicate with the Director of the Lick Observatory before April 20th, and after that date with Professor W. W. CAMPBELL, Lick Observatory Eclipse Expedition, Atlanta, Georgia.

JAMES E. KEELER.

ELEMENTS OF COMET *a* 1900 (GIACOBINI).

This comet was discovered by GIACOBINI at Nice, on January 31st, the position of discovery being R. A. $2^h\ 57^m\ 44^s$, Decl. $-7^\circ\ 55'$. The first accurate position received at the Lick Observatory was that of February 3d, obtained by JAVELLE at Nice. After the receipt of the announcement of discovery the weather at Mount Hamilton was stormy, and only cleared when the Moon was too near the comet's place to warrant a search. The first observation obtained here was on February 16th, and the next on the 21st. From these three observations I have deduced the following parabolic elements:—

$$\begin{array}{rl} T = & \text{1900, April 29.0781, G. M. T.} \\ \omega = & \left.\begin{array}{lll} 24^\circ & 36' & 56''.6 \\ \Omega = 40 & 24 & 38\ .8 \\ i = 146 & 25 & 22\ .2 \end{array}\right\} 1900.0 \\ \log q = & 0.123476 \end{array}$$

Residuals Obs. – Comp.

$$\begin{array}{ll} \Delta\lambda' \cos\beta' & -0''.4 \\ \Delta\beta' & +0\ .1 \end{array}$$

An ephemeris from these elements shows that the comet will continue to move slowly west and north for the next four months. On July 1st its position will be $\alpha = 23^h\ 40^m$; $\delta = +42°$; and on August 1st, $\alpha = 19^h\ 33^m$; $\delta = +41°$. It will probably be invisible from the latter part of the present month until the end of May, owing to its proximity to the Sun. The comet is rather faint, being estimated as between the 10th and 11th magnitudes. It is nearly round, about 2′ in diameter, and has a faint nucleus.

MT. HAMILTON, March 2, 1900. C. D. PERRINE.

ASTRONOMICAL TELEGRAMS.

(Translations.)

Professor J. E. KEELER, CAMBRIDGE, Mass., Feb 1, 1900.
Lick Observatory: (Received 1:03 P.M.)

Kiel cables that a comet was discovered by GIACOBINI at Nice on Jan. $31^d.292$ G. M. T. in R. A. $2^h\ 57^m\ 44^s$; Decl. —7° 55′. The position is only approximate.

(Signed) EDWARD C. PICKERING.

Professor JAMES E. KEELER, BOSTON, Mass., Feb. 2, 1900.
Lick Observatory: (Received 5 P. M. Feb. 4.)

Kiel cables that faint Comet *a* was observed at Nice by JAVELLE on Feb. $3^d.2893$ G. M. T. in R. A. $2^h\ 49^m\ 51^s.0$; Decl. — 6° 40′ 10″. Daily motion in R. A. 39° W.; in Decl. 25′ N.

(Signed) E. C. PICKERING.

CAMBRIDGE, Mass.,
To Professor JAMES E. KEELER, Feb. 21, 1900.
Lick Observatory: (Received 12:50 P.M.)

Kiel cables that Comet *a* was observed by JAVELLE at Nice on Feb. $17^d.3148$ G. M. T. in R. A. $2^h\ 22^m\ 2^s.8$; Decl.— 1° 19′ 27″. There is some error in the cablegram, for the control word does not check. (Signed) E. C. PICKERING.

LICK OBSERVATORY, Feb. 26, 1900.
To Harvard College Observatory: (Sent 10:20 A.M.)

Elements and ephemeris of Comet *a* have been computed by PERRINE as follows:

$$T = \text{April } 29^d.08 \text{ G. M. T.}$$

$$\left.\begin{array}{rrr} \omega = & 24° & 37' \\ \Omega = & 40 & 25 \\ i = & 146 & 25 \end{array}\right\} \text{Equinox of 1900.0}$$

$$q = 1.3289$$

(Signed) JAMES E. KEELER.

[The ephemeris is here omitted.]

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Professor **GEORGE E. HALE**, Director of the Yerkes Observatory; Professor **K. F. KÜSTNER**, Director of the University Observatory of Bonn; Professor **ROBERT HELMERT**, Director of the Prussian Geodetic Institute; and Dr. **JUAN M. THOME**, Director of the National Observatory of the Argentine Republic, have recently been elected foreign members of the Royal Astronomical Society.

M. **POINCARÉ** has been awarded the gold medal of the Royal Astronomical Society.—*Science, February 9th.*

The Directors of the Benjamin Apthorp Gould Fund announce that they are prepared to make another distribution of the income of the fund. The money is given to aid in carrying out special astronomical investigations. Applications should be sent to Dr. **S. C. CHANDLER** or Professor **ASAPH HALL**, Cambridge, or to Professor **LEWIS BOSS**, Albany.

Science, February 23, 1900, states that the Trustees of the Western University of Pennsylvania have decided to begin the erection of the new building for the Allegheny Observatory. It will be situated in Riverview Park, and will cost $250,000.

The American Academy of Arts and Sciences has recently given $500 from the income of the Rumford fund to Harvard College Observatory, to carry out an investigation of the brightness of faint stars.

A bill has been introduced in Congress to provide for the reorganization of the Naval Observatory along lines suggested in the report of the Board of Visitors.

Dr. **W. S. EICHELBERGER**, for some time computer in the Nautical Almanac Office and the Naval Observatory, has been appointed Professor of Mathematics in the United States Navy and stationed for duty at the Naval Observatory.

Señor JULIO GARAVITO, Director of the Bogota Observatory, has printed a small pamphlet in which he describes the determination of the latitude of the observatory by a modification of TALCOTT'S method. The instrument used was a two-inch field theodolite.

The modification of TALCOTT'S method consists in setting the horizontal thread a little below the meridian altitude of the lowest star, and noting the interval between the transits of each star over the same thread, before and after the meridian passage. The observations are afterwards reduced to the meridian altitude in the usual manner. No micrometer is required. The rate of the timepiece is important, but not the actual correction; and as all the observations are made at the same altitude, there are no corrections for differential refraction. The level attached to the vertical circle is used for determining variations of inclination.

With respect to accuracy, the observations are quite satisfactory, the probable error of a determination from one pair of stars being $\pm 1''.5$. The writer modestly describes himself as "hardly more than a lover of astronomy," and regards the results of his method as being therefore all the more satisfactory. Carrying out the individual observations to $0''.001$ is, however, about the only evidence of unfamiliarity with practical astronomical work.

It would seem that the principal advantage of Señor GARAVITO'S method is, that it requires no micrometer, so that it can be applied to any altitude and azimuth instrument. With respect to precision it cannot be regarded as any improvement on the ordinary method, since the greatest source of inaccuracy — the uncertainty of the level indications — remains unchanged.

The *Astronomical Journal* for February 12th contains a very suggestive article by Professor SIMON NEWCOMB, on the distribution of the mean motions of the minor planets. Astronomical students looking for a subject of a doctor's thesis might do well to look at it.

In *Nature* for January 4th and 11th there is a very interesting article by Sir NORMAN LOCKYER describing the eclipse expedition to Viziadurg, in January, 1898.

The *Astrophysical Journal* for January contains a valuable article on eclipse problems by Professor GEORGE E. HALE.

No one who intends to make observations at the coming eclipse should fail to read it.

In a number of illustrations which have recently appeared, the great telescope now under construction for the Paris Exposition of 1900 is represented as projecting views of heavenly bodies upon a screen in a darkened room, where they are viewed by a large audience; and an article in *Nature* (December 21, 1899) states that "an image of the Moon 16 meters in diameter, and of *Mars* 3.70 meters in diameter, are promised to the *abonnés*."

If such promises have actually been made, it would seem to be worth while for somebody to point out in advance their utter absurdity, since the daily press will certainly attribute them to astronomers. The area of the image of *Mars*, as above stated, is 8.8 times the area of the object-glass (1.25 meters diameter) through which all the light in the image must pass, and this number represents the ratio of illumination of object-glass and screen. In other words, the screen will be only about one-ninth as bright as a sheet of paper placed outdoors, where *Mars* (and no other source of light) can shine on it. The image on the screen will be further dimmed by loss of light in the apparatus; but whether it is a few dozen or score of times brighter or fainter makes little difference, as it will be equally invisible under all these circumstances.

The eye-end of the telescope will be large enough to hold a magic lantern, with which fine views of the heavenly bodies could be projected on the screen, and the telescope would then be independent of the weather. Possibly this is what is meant in the promises to subscribers.

HENRY HOLT & Co. have recently issued a new elementary astronomy by Dr. E. S. HOLDEN. From a hasty examination it seems that the work of both the author and the publishers has been well done. The material is well arranged, and the cuts and figures, of which there are many, are for the most part excellent. One exception to the last statement may be found in figure 207, the Moon passing near the *Pleiades*. The figure of the crescent Moon extends considerably beyond a semicircle, the terminator is the arc of a circle instead of an ellipse, three stars are within the horns of the Moon, and the crescent has an impossible position with reference to the stars of the cluster.

In discussing the double canals of *Mars* Dr. HOLDEN offers an explanation not before given in any text-book. On page 310 we find the following:—

> "Marvels of ingenious speculation have been printed to explain why 'intelligent inhabitants' having one 'canal' not sufficient for 'commerce' did not widen it, but preferred to dig another parallel to it, and why this second 'canal' sometimes vanishes altogether in 'a few hours.' Recent experiments have proved that these companion canals are optical illusions produced by fatigue of the eye and by bad focusing. Some, at least, of the single narrow dark streaks ('canals') have a real existence. It is probable that many of those laid down and named on the maps of SCHIAPARELLI, LOWELL, and others are mere illusions. It is likely that all the double canals were so."

We do not know the nature of the experiments to which Dr. HOLDEN refers; but we believe that the idea that many of the markings supposed to have been seen on *Mars*, *Venus*, and *Mercury* are optical illusions of some nature has steadily gained ground for some time. Any adequate explanation of these peculiar markings will be welcomed by astronomers.

The Harvard College Observatory intends to search for an intermercurial planet by means of photography during the total eclipse of the Sun on May 28th. Four lenses, each having an aperture of five inches and a focal length of eleven feet four inches, "will be placed on one mounting, in such a manner as to photograph a region extending for sixteen degrees on either side of the Sun, and a breadth of ten degrees throughout its length." From experiments recently made at Cambridge, Professor PICKERING is led to believe that all stars brighter than the eighth magnitude which are in the region about the Sun will make a sensible impression on the photographic plate during the total phase of the eclipse.

Within the past few weeks the astronomical world has lost by death two well known observers and two generous friends. Dr. CARL THEODOR ROBERT LUTHER, for many years Director of the Düsseldorf Observatory, was well known for his work on the minor planets; Dr. GEORGE RÜMKER, Emeritus Director of the Hamburg Observatory, was recognized as an able observer of comets and asteroids, and, in addition, was known for the attention he gave to all questions relating to the improvement of navigation.

Mr. LEANDER J. MCCORMICK, who died recently in Chicago at the age of eighty-one, will be remembered by astronomers for his generous gift to the University of Virginia of the splendid 26-inch Clark refractor and of the observatory in which it is housed.

Members of this Society will experience in common with astronomers the world over a personal sense of loss in learning of the death of Miss CATHARINE WOLFE BRUCE. From the *Astrophysical Journal* for March we quote the following paragraph:—

> "For years confined to her room by an ever-increasing illness, and personally known by but few of the many who have benefited by her bounty, Miss BRUCE has nevertheless endeared herself to men of science at home and abroad, aiding as perhaps no other has done the progress of research. Recognizing no national boundaries, giving assistance where it was most needed, and seeking no fame for herself, Miss BRUCE may well be regarded as one of the most sympathetic and generous patrons astronomy has ever known. Many a project, which without her assistance would have come to naught, has been successfully developed through her aid. Many an advance in our knowledge of the heavens is due directly to the help she gave. The appeals that came to her from far and wide were received with the kindliest consideration, both by herself and also by her sister, Miss M. W. BRUCE, who often acted in her stead. Astronomers in almost every country of the civilized world know from their own experience how prompt was the response and how often it took the affirmative form. In common with many others who have received less direct advantage from her gifts to science, they will sincerely mourn her loss."

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, ON SATURDAY, NOVEMBER 25, 1899, AT 2 P.M.

Mr. BURCKHALTER presided. A quorum was present.

The purpose of the meeting being the Third Award of the Bruce Gold Medal, the letters received from the Directors of the six nominating Observatories were submitted by the Secretary. After a careful consideration of the recommendations contained in these letters, the selection of the Medalist was made by ballot, and the following certificate of bestowal was signed by all Directors present:—

SAN FRANCISCO, November 25, 1899.

THIRD AWARD OF THE BRUCE MEDAL.

We, the undersigned Directors of the Astronomical Society of the Pacific, hereby certify, that, in accordance with the Statutes for the bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day, at 2 o'clock P. M., for the purpose of awarding the medal for the year 1900; and that, the provisions of the Statutes relating to its bestowal having been complied with, the medal was awarded to—

DAVID GILL,

for Distinguished Services to Astronomy, by the consenting votes of eleven Directors.

Signed: CHAS. BURCKHALTER W. W. CAMPBELL (by proxy), CHAS. B. HILL (by proxy), JAMES E. KEELER (by proxy), E. J. MOLERA, ROSE O'HALLORAN, GEO. C. PARDEE (by proxy), C. D. PERRINE, WM. M. PIERSON, OTTO VON GELDERN (by proxy), F. R. ZIEL.

Adjourned.

In answer to a letter addressed to Dr. GILL, notifying him of the action taken by the Directors, the following letter of acceptance was received:—

ROYAL OBSERVATORY, CAPE OF GOOD HOPE,
January 11, 1900.

F. R. ZIEL, Esq., *Secretary Astronomical Society of the Pacific:*

My Dear Sir: I have the honour to acknowledge receipt of your letter dated 1st January, 1900, stating that your Board of Directors has awarded to me the Third Bruce Gold Medal of the Astronomical Society of the Pacific.

Permit me in reply to express the gratification which the acceptance of this medal affords me, because of the distinguished names of the previous laureates, the excellent Statutes which regulate its bestowal, and the unanimous character of the award.

Above all, I value this medal as indicative of good will and kindly feeling on part of American Astronomers towards me,—feelings which, believe me, I most sincerely reciprocate.

Yours very sincerely,
Signed: DAVID GILL.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, MARCH 31, 1900, AT 7:30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 31, 1900.

Dr. G. DEL AMO	1705 Bush St., S. F., Cal.
Mr. ARTHUR ROYDEN MERRITT	432 West 16th St., New York City, N. Y.

The Library Committee presented its report as follows, and the report was, on motion, adopted and filed:—

To the Board of Directors of the Astronomical Society of the Pacific:

We, the undersigned Committee on the Society's Library, report as follows:—

During the past year 74 volumes, not including unbound books and pamphlets, have been added to the shelves of the library by gift, purchase, and binding. The total number of volumes in the library, as shown by the accessions book, is 1,116.

The Committee wishes to call the attention of the Directors to the crowded condition of the shelves, and of the drawers for pamphlets. Relief must be provided soon.

The following is an account of the expenditures from the Alexander Montgomery Library Fund for the year ending March 31, 1900:—

1899, June 12.	*Astronomical Journal*, Vol. I	$ 9 00
Dec. 5.	Petty expenses	1 75
1900, Feb. 9.	Subscription to *Popular Astronomy*	2 50
Mar. 6.	Hicks-Judd Co., for binding	37 70
	Total	$50 95

Respectfully submitted,

SIDNEY D. TOWNLEY, *Librarian.*
ROSE O'HALLORAN.

The following resolution was, on motion, adopted:—

WHEREAS, The Russian Astronomical Society is desirous of obtaining a copy of the Donohoe Comet-Medal, be it

Resolved, That one of the unengraved medals belonging to the Society is herewith presented to the Russian Astronomical Society.

Adjourned.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, MARCH 31, 1900, AT 8 P. M.

The meeting was called to order by Mr. BURCKHALTER. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented :—

1. Address of the retiring President of the Society in Conferring the Bruce Medal upon Dr DAVID GILL, by GEORGE C. PARDEE.
2. Reports of Committees: on Nominations; on the Comet Medal; on Auditing; and Annual Report of the Treasurer.
3. Astronomical Observations in 1899, by TORVALD KÖHL.
4. The Chabot Observatory—Dolbeer Eclipse Expedition, May 28, 1900, by CHAS. BURCKHALTER.
5. Planetary Phenomena for May and June, 1900, by MALCOLM MCNEILL.
6. Visual Observations of the Moon and Planets made at Harvard College Observatory, by EDWARD S. HOLDEN.
7. Some Computations relative to the Solar Eclipse of May 28, 1900, by S. C. PHIPPS.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. CHAS. BURCKHALTER, W. W. CAMPBELL, JOHN DOLBEER, C. B. HILL, JAMES E. KEELER, E. J. MOLERA, Miss R. O'HALLORAN, Messrs. C. D. PERRINE, WM. M. PIERSON, S. D. TOWNLEY, F. R. ZIEL.

For Committee on Publication: Messrs. R. G. AITKEN, S. D. TOWNLEY, O. VON GELDERN.

Messrs. TOWNLEY and MCCONNELL were appointed as tellers. The polls were open from 8:15 to 9 P. M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE COMET-MEDAL, SUBMITTED MARCH 31, 1900.

This report relates to the calendar year 1899. The comets of 1899 have been:

Comet *a* (unexpected comet), discovered by Dr. LEWIS SWIFT, Director of the Lowe Observatory, on March 3d.

Comet *b*, TUTTLE's periodic comet, re-discovered by Professor MAX WOLF, at Heidelberg, on March 5th.

Comet *c*, TEMPEL's second periodic comet, re-discovered by Mr. C. D. PERRINE, Assistant Astronomer in the Lick Observatory, on May 6th.

Comet *d*, HOLMES's periodic comet, re-discovered by Mr. C. D. PERRINE, Assistant Astronomer in the Lick Observatory, on June 10th.

Comet *e* (unexpected comet), discovered by M. MICHEL GIACOBINI, at the Nice Observatory, on September 29th.

The Comet-Medal has been awarded to the discoverers of Comets *a* and *e*, in accordance with the regulations.

Respectfully submitted,

JAMES E. KEELER,
WM. M. PIERSON,
CHAS. BURCKHALTER.

The Treasurer submitted his Annual Report as follows:—

ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 31, 1900.

GENERAL FUND.

Receipts.

Cash Balance, March 25, 1899		$224 55
Received from dues	$1060 20	
" " sale of publications	44 00	
" " " " stationery	2 40	
" " advertisements	35 00	
" " Security Savings Bank (interest)	28	
" " Life Membership Fund (interest)	76 74	
" " Bruce Medal Fund, advance of Feb. 27, 1899, returned	59 97	
	$1278 59	
Less transfer to Life Membership Fund	50 00	1228 59
		$1453 14

Expenditures.

For publications: printing	$739 70		
" " : illustrations (cuts)	26 36		
		$766 06	
Stationery and printing		59 15	
Postages		77 22	
Rent		180 00	
Salary Secretary-Treasurer		180 00	
Expressages		5 10	
Janitor and elevator		6 50	
Gas		1 30	
Taxes		2 45	
Insurance premiums		22 50	
Telegrams		2 90	
Collecting dues		10 50	
Lantern at lecture, and lecturer's expenses		17 75	
Engrossing diplomas		2 40	
Engraving two comet medals (Nos. 36 and 37)		2 00	
Typewriting and exchange		60	
			$1336 43
			$116 71
Mar. 8, 1900. Advanced to Bruce Medal Fund (third award)			81 62
Cash Balance, March 31, 1900			$35 09

LIFE MEMBERSHIP FUND.

Cash Balance, March 25, 1899	$2053 95
Received from General Fund	50 00
" " Interest for 1899	76 74
	$2180 69
Less interest transferred to General Fund	76 74
Cash Balance, March 31, 1900	$2103 95

DONOHOE COMET-MEDAL FUND.

Cash Balance, March 25, 1899	$641 72
Interest for 1899	23 97
Cash Balance, March 31, 1900	$665 69

BRUCE MEDAL FUND.

Cash Balance, March 25, 1899		$2500 00
Interest for 1899		80 30
March 8, 1900. Cash advanced by General Fund for Third Award		81 62
		$2661 92
Oct. 4, 1899. Cash of Feb. 27, 1899, returned to General Fund	$59 97	
March 9, 1900. Remittance to A. DuBois for one Gold Medal (Third Award)	101 95	161 92
Cash Balance, March 31, 1900		$2500 00

ALEXANDER MONTGOMERY LIBRARY FUND.

Cash Balance, March 25, 1899			$1517 90
Interest for 1899			56 16
			$1574 06
Less expenditures:	Vol. 1, Astronomical Journal	$9 00	
	Subscription, Popular Astronomy	2 50	
	Librarian	1 75	
	Hicks-Judd Co., for binding	37 70	50 95
			$1523 11

FUNDS.

Balances on Deposit as follows:

General Fund:		
with Donohoe Kelly Banking Co	$25 33	
" Security Savings Bank	9 76	
		$35 09
Life Membership Fund:		
with San Francisco Savings Union	$903 95	
" German Savings and Loan Society	600 00	
" Hibernia Savings and Loan Society	600 00	
		$2103 95
Donohoe Comet-Medal Fund:		
with San Francisco Savings Union	$221 95	
" German Savings and Loan Society	216 43	
" Hibernia Savings and Loan Society	227 31	
		$665 69
Alexander Montgomery Library Fund:		
with San Francisco Savings Union	$502 87	
" German Savings and Loan Society	416 06	
" Hibernia Savings and Loan Society	604 18	
		$1523 11
Bruce Medal Fund:		
with San Francisco Savings Union	$1250 00	
" Security Savings Bank	625 00	
" German Savings and Loan Society	625 00	
		$2500 00
		$6827 84

San Francisco, March 31, 1900. F. R. Ziel, *Treasurer.*

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted :—

To the President and Members of the Astronomical Society of the Pacific:

Gentlemen — Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 31, 1900, have made a careful examination, and find same to be correct.

Yours respectfully,

O. von Geldern,
F. H. McConnell.

March 31, 1900.

The following resolution was, upon motion by Mr. PIERSON, adopted:—

Resolved, That in the death of Miss CATHERINE WOLFE BRUCE, which has just been announced to this Society, science has suffered an irreparable loss, and this Society a sympathizing and generous friend. Although suffering for years from a painful illness, she yet rarely refused to stretch forth a bounteous hand in aid of astronomical science. To recount her gifts were needless, for they are part of the annals of the scientific world. Her munificent endowment of the Gold Medal Fund of this Society will stand as a perpetual memorial of her love for astronomy, and the bestowal of the medals she provided, a constantly recurring remembrance both to us and to the recipients of them, of her gracious efforts in aid of the cultivation and diffusion of scientific truth.

The Secretary was directed to forward to Miss M. W. BRUCE a copy of these resolutions.

Mr. CUSHING then read President PARDEE's annual address.

The following resolution was, on motion, adopted:—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY,

MARCH 31, 1900, AT 9:30 P. M.

The new Board of Directors was called to order by Mr. BURCKHALTER. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers and committees for the ensuing year, the following officers and committees, having received a majority of the votes cast, were duly elected:—

President: Mr. JAMES E. KEELER.
First Vice-President: Mr. CHAS. BURCKHALTER.
Second Vice-President: Miss R. O'HALLORAN.
Third Vice-President: Mr. S. D. TOWNLEY.
Secretaries: Messrs. C. D. PERRINE and F. R. ZIEL.
Treasurer: Mr. F. R. ZIEL.

Committee on the Comet-Medal: Messrs. KEELER (*ex-officio*), PIERSON, and BURCKHALTER.

Library Committee: Mr. TOWNLEY, Miss O'HALLORAN, Miss HOBE. Mr. TOWNLEY was appointed Librarian.

Finance Committee: Messrs. PIERSON, BURCKHALTER, HILL.

The Committee on Publication is composed of: Messrs. R. G. AITKEN, S. D. TOWNLEY, O. VON GELDERN.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. James E. Keeler	*President*
Mr. Charles Burckhalter	*First Vice-President*
Miss R. O'Halloran,	*Second Vice-President*
Mr. S. D. Townley	*Third Vice-President*
Mr. C. D. Perrine Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Burckhalter, Campbell, Dolbeer, Hill, Keeler, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Burckhalter, Hill.

Committee on Publication—Messrs. Aitken, Townley, von Geldern.

Library Committee—Messrs. Townley, Miss O'Halloran, Miss Hobe.

Committee on the Comet-Medal—Messrs. Keeler (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

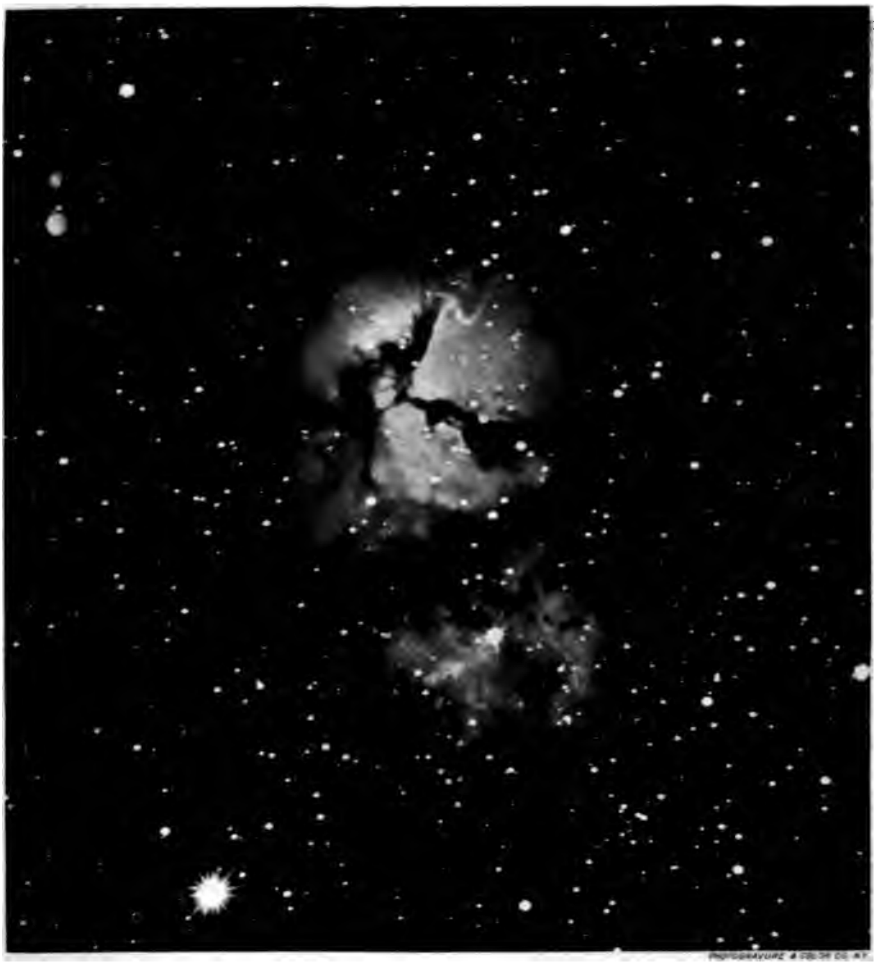
It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)



PHOTOGRAVURE & COLOR CO. N.Y.

THE TRIFID NEBULA IN SAGITTARIUS.

Photographed with the Crossley Reflector
of the Lick Observatory

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XII. SAN FRANCISCO, CALIFORNIA, JUNE 1, 1900. No. 74.

PHOTOGRAPH OF THE TRIFID NEBULA, IN *SAGITTARIUS.*

BY JAMES E. KEELER.

The "Trifid" Nebula, *Messier 20*, in *Sagittarius*, is one of the most beautiful and remarkable of the irregular nebulæ. Its name is derived from the appearance which it presents in visual telescopes, and more particularly from the description of Sir JOHN HERSCHEL:—

> "One of them [several nebulæ in *Sagittarius*] is singularly trifid, consisting of three bright and irregularly formed nebulous masses, graduating away insensibly externally, but coming up to a great intensity of light at their interior edges, where they inclose and surround a sort of three-forked rift, or vacant area, abruptly and uncouthly crooked, and quite void of nebulous light. A beautiful triple star is situated precisely on the edge of one of these nebulous masses just where the interior vacancy forks out into two channels. A fourth nebulous mass spreads like a fan or downy plume from a star at a little distance from the triple nebula." *

Numerous drawings of the Trifid Nebula have been published. Two by LASSELL in the *Memoirs of the Royal Astronomical Society* represent the brightest parts of nebula very well. There is a good drawing by TROUVELOT, showing the whole nebula, among the astronomical drawings in volume VIII of the *Annals of the Harvard College Observatory*. It has been copied into a number of popular books on astronomy.

The photogravure of the Trifid Nebula which accompanies the present article was made from a photograph taken with the Crossley reflector on the night of July 6, 1899. The exposure given to the original negative was three hours. The enlargement of the photogravure, as compared with the negative, is 2.9 diameters, and $1^{mm} = 13$ seconds of arc.

---

* "Outlines of Astronomy," p. 611.

The photograph agrees well with the drawings, but it shows very much more than they do. The three main rifts referred to in Sir JOHN HERSCHEL'S description are seen, ramifying in all directions, like the roots of a tree, and may be traced nearly to the limits of the plate. Besides these rifts, there are many others, extending through the fainter part of the nebula, which in TROUVELOT'S drawing is represented by a uniform patch of nebulosity.

The triple star, referred to by HERSCHEL, and shown in the different drawings which have been mentioned, is, on the photograph, lost in the bright patch of nebulosity bordering on two of the main rifts. It is visible on the negative, but could not be brought out on the enlargement.

According to Dr. HOLDEN, the observations and drawings of this nebula afford strong evidence that there has been a change in the relative position of the nebula and some of the involved stars. A drawing by HERSCHEL in the *Philosophical Transactions* (1833) shows the triple star in the middle of the dark space formed by the three principal lanes, and in several early observations the star is stated to have this position. Later observations and drawings place the star just within the outline of the nebula. But Dr. DREYER has pointed out that the drawing of 1833 was constructed from sketches "the rudest imaginable, aided by memory," while the observations were made under unfavorable circumstances. A drawing made by Sir JOHN HERSCHEL in 1835 shows the star in its present position. The change, if there was one, must have occurred suddenly, which is not, in general, the nature of cosmical changes. Since 1835 there has been no change in the relative positions of the star and the nebula. In all probability, therefore, the inferred proper motion of the nebula is illusory.

It is certain that the more frequently one has to compare drawings and photographs of nebulæ, the less one is inclined to attach weight to evidence based on the drawings.

NOTES ON THE PROGRESS OF DOUBLE-STAR ASTRONOMY.*

By WILLIAM J. HUSSEY.

It is nearly a hundred years since Sir WILLIAM HERSCHEL, as a result of the comparison of measures which he had just obtained with others made by him some twenty years earlier, was able to announce half a dozen cases in which he had found one star revolving about another. At that time this was a wonderful discovery. Astronomers had not expected to find suns moving in this manner, and it is not surprising that they were amazed when HERSCHEL proved this to be the case by producing such an array of facts and arguments that no room was left to doubt the correctness of his conclusions.

Previously but little attention had been given to the stars for their own sakes. With instruments such as were in use, perhaps it was thought that not much of interest could be ascertained concerning them. As reference-points in the sky they had been of use (and are so still) in facilitating the investigations of the motions of the bodies composing the solar system, and it does not appear to have been imagined that there is great variety among them. HERSCHEL'S discovery was one of the factors which have operated to change all this. He showed that the stars are not all after the same pattern, but that they have their several stories to tell to those who will interrogate them properly, and ever since his time astronomers have more and more been finding this to be the case. New departments of sidereal investigation have come into existence. Besides all that relates to the absolute positions and movements of the stars as determined by the meridian observations, and those relative changes which are ascertained from the micrometrical measures, there are the extensive fields of research in which are considered those strange variations of light exhibited by certain of the stars, and the multiplied diversity of phenomena which have been revealed by the study of stellar spectra. With larger telescopes, more efficient subsidiary apparatus, more exact theories of instruments and methods, and a greater number of enthusiastic investigators, results of greater variety and ever-increasing interest and importance are being obtained. In this rapid movement forward which now characterizes sidereal astronomy, that part which relates to double stars, visually considered, follows methods which have been in use for many years, and it appears probable that this will continue to be the case for all of the more interesting systems.

---

*This article does not pretend to cover the entire field of double-star astronomy. It gives no account of the numerous determinations of orbits which have appeared from time to time, and nothing concerning spectroscopic binaries of which quite a number have recently been discovered.

The number of stars which have been catalogued as double and multiple has reached the formidable aggregate of over thirteen thousand. The majority of these are the discoveries of long ago. The catalogues of the HERSCHELS and the STRUVES alone contain more than nine thousand entries. But many of these are wide and easy pairs, whose components sustain no known physical relation to each other, and which are of such a character that were they now found for the first time no one would think of cataloguing them as double stars.

For nearly forty years, dating from 1782, Sir WILLIAM HERSCHEL was almost the only observer of double stars. Eight hundred and twelve of those which he observed have been identified. Many of these were his own discoveries, and all of the more important ones were included by STRUVE in the Dorpat Catalogue.

Sir JOHN HERSCHEL began his long career in astronomy in 1816 by taking up, under his father's direction, the re-examination of all the double stars discovered by him. By a fortunate circumstance, he worked from 1821 to 1823 in conjunction with Sir JAMES SOUTH, at the latter's private observatory in London. This was provided with two telescopes of very modest dimensions according to our present standards. One was three and three-quarters and the other five inches aperture. With these little instruments, not supplied with driving-clocks, these observers made a series of observations of 380 double stars, which is remarkable for the skill, patience, and accuracy with which it was executed, and for the confirmation of the phenomena first brought to light by Sir WILLIAM HERSCHEL.

These observations of SOUTH and HERSCHEL were published in the *Philosophical Transactions* for 1824, and won for them the Lalande Prize of the French Academy in 1825, and gold medals from the Royal Astronomical Society in the following year. At the same time this society presented its gold medal to WILLIAM

STRUVE for the double-star observations which he had made at Dorpat, and made honorable mention of the work of AMICI at Modena in the same direction. These four were the only double-star observers then living.

Previous to this time STRUVE had been using a very modest telescope in his double-star work. But in 1824 FRAUNHOFER completed for the Dorpat Observatory the celebrated refractor of nearly nine and a half inches aperture. This was equatorially mounted, and provided with a good driving-clock. For fifteen years it remained the largest refractor in the world, and during that time it was by far the most efficient telescope in existence for double-star work.

On receiving this equatorial, STRUVE resolved to reobserve all the double stars then known from the north pole to 15° South Declination, and to examine carefully all the brighter stars within this region for the purpose of discovering new pairs. In the course of this survey he is said to have examined no fewer than 120,000 stars. As a result of the first two years' work upon this programme, he published in 1827 the Dorpat Catalogue of 3,065 double and multiple stars. In this were included not only his own discoveries, but also all other objects which had been found by other astronomers within 105° of the north pole, and which appeared to him worthy of being called double stars.

The second part of STRUVE's programme was more arduous and required a greater time. To obtain exact micrometrical observations of all the double stars of the Dorpat Catalogue which are worthy of attention is no small undertaking, and it is surprising that STRUVE accomplished it in the comparatively short interval of twelve years. In 1837 he published the "Mensuræ Micrometricæ," a ponderous folio, containing the observations made at Dorpat with the large equatorial from 1824 to 1836, together with the results which he had obtained with a smaller instrument from 1813 to 1824. It also contained many of the observations by the HERSCHELS and SOUTH, so that it may be said that this volume gave all that was known at the time of its publication concerning the double stars of the Dorpat Catalogue. When the objects of this catalogue came to be critically examined, it was found that some had distances greater than 32", which was the maximum limit set by STRUVE; that some were not double; that some were identical with others, erroneous positions having been assigned to them. For these and various other reasons 492 were rejected, or about sixteen per cent. of the entire number.

About 1827, Sir JOHN HERSCHEL began a series of "sweeps" with large reflecting telescopes, which resulted in the discovery of large numbers of nebulæ and 5,533 double and multiple stars. Some of these are in the northern and some in the southern hemisphere. Many of these double stars have little claim to be called such, consisting, as they frequently do, of wide pairs of faint stars. Many of them have not been measured since their discovery, and even at that time the angles alone were measured, the distances were estimated. Taken as a whole, they are of little consequence, except that they swell enormously the number of objects listed as double stars.

In 1839 the great Russian Observatory at Pulkowa was established, and WILLIAM STRUVE was called from Dorpat to be its first Director. Its largest instrument was the 15-inch refractor. With this, in 1841 and 1842, OTTO STRUVE examined all the brighter stars north of the equator, and by doing so discovered a large number of close and difficult double stars. His first catalogue contains 514 objects, which subsequent discoveries increased to 547. In this catalogue it was intended that the distances should all be less than 32″, and the magnitude of the principal star, or the combined magnitude of the two in the case of close doubles, not to descend below 7.8. As companions all stars at distances less than 16″ and bright enough to be readily measurable with the 15-inch telescope were admitted, while for distances between 16″ and 32″ the limiting inferior magnitude was 8.9. When the stars came to be measured, it was found that some fell outside of the limits just described, and for this and other reasons 106 of the objects enumerated in the first edition of the Pulkowa Catalogue were rejected.

Sir WILLIAM HERSCHEL'S work on double stars had begun in his attempt to find suitable pairs of stars for the determination of stellar parallaxes. Having satisfied himself that in these investigations the method of double stars would have many advantages over any other, he states that he resolved to examine every star in the heavens with the utmost attention and with a very high power, in order to ascertain what stars are best suited to this research, so that he might make his observations on those that promised the best results.

We have noted that WILLIAM STRUVE examined no less than

120,000 stars within 105° of the north celestial pole with the Dorpat refractor, for the express purpose of discovering those which are double. Sir JOHN HERSCHEL swept both the northern and the southern heavens in quest of double stars and nebulæ. Finally OTTO STRUVE made the Pulkowa refractor famous by reason of the large number of difficult double stars which he discovered with it, in the course of his examination of all the brighter stars in the northern sky. After all of these examinations by experienced observers armed with powerful telescopes, it is no wonder that the astronomers at the middle of the nineteenth century were disposed to think that all or nearly all of the interesting double stars had already been discovered, and that what remained to be accomplished in this field was to continue the observation of those already known and to compute the orbits of the binaries whenever the data for the purpose became sufficient. For thirty years following the publication of the Pulkowa Catalogue very few double stars were discovered. During this time, however, some remarkable series of observations were obtained. To this period belong the observations by OTTO STRUVE, MADLER, DAWES, SECCHI, and DEMBOWSKI, not to mention others. Their observations have served to determine the character of the motion, where any is shown, in the great majority of the stars contained in the Dorpat and Pulkowa catalogues; and if the information which is now scattered through many publications were brought together and printed in convenient form, the astronomers of the future would have but little difficulty in ascertaining what further attention, if any, is desirable in the case of any of the double stars contained in these extensive catalogues. Such publication of the data now available would most effectively advance the interests of this department of astronomy, by practically removing from consideration the large numbers of these stars which have shown little or no motion, and explicitly pointing out those which are in need of further attention.

The revival of the discovery of double stars dates from 1873, when BURNHAM began to publish accounts of those which he found with his 6-inch telescope at Chicago. In this year he published three catalogues in the *Monthly Notices* of the Royal Astronomical Society, announcing 182 new double stars. Since that time discovery has proceeded rapidly, as is shown by the following summary, which gives approximately the numbers of

NEW DOUBLE STARS DISCOVERED BY VARIOUS OBSERVERS SINCE 1870.

BURNHAM	1,290
HOUGH	623
SEE	500
INNES	305
Cincinnati Observatory observers	181
Washburn Observatory observers	171
Harvard and Arequipa observers	109
HUSSEY	100
AITKEN	47
Miscellaneous, perhaps about	200
	3 526

This list does not profess to be complete. It is merely intended to indicate the large number of discoveries which have been made during the past thirty years. It is well known that several observers have recently found considerable numbers of new double stars which are still unannounced.

The double stars of the lists above include a great majority of the closest and most difficult pairs known, and a large number of rapid and interesting binaries. Professor BURNHAM'S discoveries alone include 690 pairs having distances not exceeding 2″, while there are only 680 such pairs among the more than nine thousand double stars that had been catalogued before 1870. The discovery of so many close and difficult stars has added enormously to the labor in this department of astronomy, but this has its compensation in the rapid increase in the number of known physical pairs, and in the important additions to our knowledge respecting them.

These circumstances have given the subject a greater interest. The number of observers has increased somewhat, but hardly in proportion to the increased number of instruments available for such work, and the literature has become much more extensive and scattered than formerly. This state of affairs has both advantages and disadvantages. A greater number of observers insures more measures, a less likelihood that important pairs will long be overlooked, and more complete data for the determinations of orbits, and of systematic and accidental errors of observation. But, on the other hand, the observations are being scattered through a great variety of publications, and it has become an exceedingly difficult matter for the average observer to ascertain what stars have already received sufficient attention and what ones should be kept on the observing list. In most cases it is far easier to make a new set of observations of a given star than to examine the literature thoroughly to see whether such observations are needed. Any additions, therefore, to the works which collect and classify the material already available in this department of astronomy makes for progress, and it is a pleasure to note that two such books, both of great importance, have recently appeared. The first volume of the Publications of the Yerkes Observatory is "A GENERAL CATALOGUE OF 1,290 DOUBLE STARS DISCOVERED FROM 1871 TO 1899 BY S. W. BURNHAM," and Part II of Volume II of the Annals of the Royal Observatory, Cape of Good Hope, is a "REFERENCE CATALOGUE OF SOUTHERN DOUBLE STARS, BY R. T. A. INNES."

Professor BURNHAM has given an excellent statement of the needs which led to the preparation of his General Catalogue in the opening words of his introduction, as follows:—

> "A general catalogue of all the double stars discovered by me from time to time during the past twenty-five years has long been needed by those interested in this field of astronomical research, and, by reason of the special interest attached to many of these remote sidereal systems, it has become more and more important to bring the scattered material together in order to intelligently pursue the investigations which promise to so much increase our knowledge of the great universe beyond the solar system. These discoveries are scattered through nineteen different catalogues, published at various times and places, commencing with 1873; and the observation of these stars by a great number of astronomers in this country and in Europe can only be made use of by consulting hundreds of volumes of observatory and society publications, astronomical periodicals, etc. It is difficult, if not practically impossible, for the general observer or investigator to make a really complete collection of all the measures of a large number of these stars. Many of the observations are in obscure and unusual places, and in works not always readily accessible."

Professor BURNHAM'S General Catalogue covers its ground very completely; and not only in the arrangement of its material, but also in its typographical effect, it is a model of excellence which may well be followed in other books of a similar character. It gives a record of all the double stars discovered by BURNHAM through a long series of years. Nothing essential to their histories is wanting, and nothing superfluous added. The stars are arranged in the order of Right Ascension. The mean results of all the observations of each pair are given in chronological order. These are followed by notes of such length as may be needed to give an account of the discovery, the character of the pair, the circumstances of its motion, and any other facts of interest or importance concerning it. Diagrams are freely used to illustrate the motions of the more interesting cases. Finally, each pair is accompanied by references to all the original sources of information.

It is not likely that the importance of this work will be overestimated. Having it at hand, it will generally be possible to see at a glance, from the data which it contains, whether the components of any given pair are in motion or not, and thus the future observer may readily select from among these stars those which are needing observation and which are likely to lead to interesting results. Moreover, this selection will be the more easy, for Professor BURNHAM has given a provisional list of 185 pairs which have already furnished more or less evidence of being physical systems. Some of these are rapidly moving binaries. The orbits of eight have already been computed. These include κ *Pegasi* whose period (11.42 years) is the shortest known among the visual binaries.

In the introduction to his volume Professor BURNHAM has given a brief history of the beginning of his astronomical career. Since this is of very general interest, I quote a portion of it, as follows:—

> "When in London, about 1861, I purchased one of the cheap astronomical telescopes introduced about that time. It had a nominal aperture of three inches, but was without a finder, and had only the simple altazimuth mounting, with a common table tripod. It was supplied with a terrestrial as well as astronomical eye-piece, and while it was a good instrument for landscape use, it was of little value for astronomical purposes. Some years later I obtained a 3¾-inch telescope, with an English object-glass, mounted equatorially by FITZ on a portable stand. This was just good enough to be of some use, and poor enough, so far as its optical power was concerned, to make something better more desirable than ever. In 1869 I accidentally met Mr. ALVAN G. CLARK in Chicago on his return from Iowa, where he had been to observe the total eclipse of that year, and made some inquiries of him concerning a small equatorial. The interview resulted in my ordering from the celebrated firm of ALVAN CLARK & SONS an equatorial of six inches aperture. I told them what I wanted and what I wanted it for. Every detail was left entirely to their judgment, stipulating only that its definition should be as perfect as they could make it, and that it should do on double stars all that it was possible for any instrument of that aperture to do. In due course of time this instrument was delivered, and was set up in an observatory prepared for it in the mean time. My attention, for

some reason or other which I am unable to explain, had been almost exclusively directed to double stars previous to this while using the smaller telescope referred to. This preference was not in any sense a matter of judgment as to the most desirable or profitable department of astronomical work, or the result of any special deliberation upon the subject. It came about naturally, without any effort or direction upon my part."

By adhering to this one line of astronomical work, becoming familiar with its extensive literature, and by a still more effective examination of the sky, Mr. BURNHAM has attained a more complete mastery of this department of astronomical work than any other man has done. All of the double stars discovered by him have been found with telescopes having objectives by ALVAN CLARK & SONS. Over eight hundred of his discoveries were made in Chicago, and nearly three hundred at the Lick Observatory. Their distribution among the several telescopes, which he used at various times, is given as follows:—

6-inch—Private Observatory	451
18½-inch—Dearborn Observatory	413
36-inch—Lick Observatory	198
15½-inch—Washburn Observatory	87
12-inch—Lick Observatory	56
9.4 inch—Dartmouth College Observatory	24
26-inch—U. S. Naval Observatory	14
40-inch—Yerkes Observatory	8
16 inch—Warner Observatory	2

The gold medal of the Royal Astronomical Society was awarded to Mr. BURNHAM in 1894 for his double-star discoveries and investigations.

Comparatively little has been done upon the double stars of the southern hemisphere, and until the appearance of Mr. INNES'S book no general catalogue of them had been published. Hitherto, observers desiring to work in that field had three courses open to them: they could spend their time in searching for suitable objects in the sky, or they could confine their attention to those in the vicinity of the equator which generally had been discovered by northern astronomers and measured by them, or they could search through many publications to ascertain what southern stars were in need of attention and likely to lead to interesting and valuable results.

Mr. INNES has done much to remove the difficulties which have confronted observers, and his book cannot fail to have a wide influence in stimulating the study of the double stars situated in a region heretofore considerably neglected. He has given descriptions of about twenty-two hundred double stars belonging to the southern hemisphere. These are arranged in the order of Right Ascension. Each pair is accompanied by a selection of the micrometrical measures which have been made upon it, and from these it is frequently possible to form an idea respecting the state of rest or motion of the components. Notes are sparingly used, and usually relate to questions of motion, magnitudes, etc. Except in a few cases, such as *Sirius* and α *Centauri*, references to original sources of information are not given in connection with each pair, but at the end of the volume we find an extensive list of books and papers "chiefly limited to treatises of general interest or such as contain observations of southern double stars."

Mr. INNES has deemed it impracticable to include in his catalogue all the objects of the southern hemisphere which at one time or another have found their way into the lists of double stars. In order to have a criterion for the rejection of undesirable pairs, he has adopted the scale of limiting distances according to magnitude given in the following table:—

Magnitude of Primary.	Limiting Distance of Components.
1	30″
2	25
3	20
4	15
5	10
6	7
7	5
8	3
9	1

In the beginning it would no doubt have been better if the limits as to distance had been more restricted, and if large numbers of wide pairs had never been catalogued. But it is difficult effectively to remove a star which has appeared in the lists; and however much we may regard the action of Mr. INNES in restricting the distances to narrow limits as a move in the right direction, we still have a lingering wish that he might have included all known pairs in his book. At times he has found it necessary to set aside the limits which he has adopted. This has been done in order to retain "many wide pairs, worthy of inclusion from some point of view." Among these are "some systems much exceeding the above distances and showing no certain signs of orbital motion," but which have been retained "on account of large proper motion common to both components." But perhaps the most serious objection to the general adoption of the above scale of distances is, that the limits for the fainter magnitudes are so narrow that some of the northern binaries would be excluded, and it is not impossible that this may also be the case with some of those of the southern hemisphere. The companion to μ *Herculis* is an example. The magnitudes of the components of this pair are 9.4, and 10, and the period in which they complete a revolution is about forty-five years. According to my measures with the thirty-six-inch refractor, the distance last year was 1".54. The last star in the Pulkowa Catalogue, OΣ *547*, is another example. The magnitudes in this case are 8.3 and 8.3, and in 1898, the distance which I obtained as a result of three nights' measures was 4".62. Not only do these stars have a common proper motion of nearly a second a year, but from the time of the first micrometrical observations the position-angle has been increasing about three fourths of a degree per year without appreciable change of distance.

In the various double-star catalogues are to be found many pairs consisting of a bright star and a distant faint companion. The distance between the components of many of these pairs is so great that they would now probably be considered unworthy of attention by any one looking for new double stars. In some cases these pairs have exhibited changes in position-angle and distance, which may be traced to the difference of the proper motions of the two stars, but the majority have shown no certain change in the relative positions of their components during the period over which the micrometrical observations extend. Nevertheless, among these pairs are many examples in which the proper motion of the principal star has been determined from meridian observations, and found to be so large that a marked change in position-angle and distance would take place in a comparatively short time, were it not that the companion has the same proper motion as the principal star. These cases are so numerous that they cannot be ascribed to fortuitous circumstances, and we are compelled to admit that the stars which are moving together in this manner are physically related. How wide may be the limits over which this physical connection extends no one at present can tell. The photographs of large nebulæ frequently exhibit arrangements of stars which so closely conform to the nebular outlines as to afford some evidence that the stars and nebula are physically associated. A nebula may cover a large area, but however extensive it may be, we entertain no doubt as to the physical connection of its various parts. With some reason, then, we may also assume a possible physical relationship of the stars which appear to be associated with it. If this be granted, we have at once a far wider limit of apparent distance than has been admitted in any of the extensive catalogues of double stars.

The considerations just given do not afford an argument of any particular force in favor of including additional wide pairs in future catalogues of double stars. It may be well to retain those which have been micrometrically measured at various epochs, and to obtain occasional additional observations of them in the future; for it may be that these measures will eventually furnish some valuable information concerning the motions which are slowly taking place among these distant sidereal systems.

But there appears to be no sufficient reason for adding to their number, as would be an easy matter with the large telescopes of the present time. On the contrary, in the case of new discoveries, there is a decided tendency to adopt limits only a little wider than is necessary to include the known binaries, to the end that the number of objects to be considered may not become unmanageably large, and that the lists may have an average higher interest. Besides, there is another consideration. Large distances can be obtained more accurately from the measurement of large-scale photographs than directly with the micrometer. On this account it is not inappropriate to leave the wide and easy pairs for photographic measurement.

The attempts which have been made to obtain the position-angles and distances of moderately close and unequal pairs through the medium of photography cannot be said to have been attended with much success, either when we consider the number of measures obtained or the character of the pairs. The photographic method has its limitations. These are such as render it worthless in investigations relating to the closest and most difficult double stars, which are the ones that include all of the rapid binaries. In this field of work the visual and the photographic methods are not competitors. The reason is simple enough. The eye can see as double what the photographic plate, used in an instrument of practicable dimensions, would certainly record as single. The images of the components of a close double star as formed by the objective of the telescope are very near each other. Thus, the scale for the 12-inch telescope of the Lick Observatory is 1/1100th of an inch to 1", and that for the 36-inch refractor 1/297th of an inch to 1". Under the most favorable circumstances the eye is able to detect the elongation produced by the partial overlapping of equal stellar images when their centers are not more than 1/5000th of an inch apart. The photographic plate does not possess resolving power to this extent. The silver grains in the film have dimensions probably twice as large. Besides, for objects such as double stars, photographic images not larger than the silver grains cannot be realized. The light spreads through the film, the area over which the photographic action extends becomes enlarged, the image of a bright star obliterates that of its faint companion, and in the case of close and equal pairs the images of the two components are merged together and lose their identity.

MT. HAMILTON, CALIFORNIA, May 29, 1900.

THE ORBIT OF *T CYGNI.* (A. G. C. 13.)

By R. G. AITKEN.

The companion to *T Cygni* was discovered by ALVAN G. CLARK in October, 1874, with the 26-inch telescope now mounted at the Leander McCormick Observatory. The first measures were secured in the same year by NEWCOMB, with the 26-inch refractor of the Naval Observatory, and by DEMBOWSKI, with an instrument of only seven inches aperture. The latter observer demonstrated the existence of relative motion in this system by his measures during the few years following discovery, and it soon became apparent that this motion was orbital. Other observers also gave the pair attention until 1880; but from that year until 1889, when BURNHAM began his work with the 36-inch refractor, it was almost wholly neglected. The only observation in this interval (during which the small star described an arc of nearly 100°) that can be used in determining the orbit is one by HALL, on a single night in 1885, to which he appends the note, "Images blazing." Since BURNHAM'S measures in 1889, the star has received sufficient attention, but the measures are not as accordant as is desirable.

An orbit for *T Cygni* was computed by GORE (*A. N.*, 2749) in 1886, using the measures to 1885. The arc, however, was so small that the resulting elements were very uncertain. He found a period of 53.87 years. In 1892, BURNHAM attempted to define the orbit using all the measures to date, including his own in 1892.41. His conclusion was that even then, when the arc described by the companion-star was nearly 180°, the discordance of the early and late measures was so great as to make it impossible to determine where the truth lay. He drew an apparent ellipse, however, which would satisfy the observations very well, provided the CLARK companion were assumed to be attended by a "dark" sun of equal mass revolving with it about a common center of gravity in a hypothetical orbit. The ellipse also satisfied the motion of the visible companion without this assumption as well as any that could be drawn at that time. The elements resulting from it are:—

$P = 36.5$ years.
$T = 1893.1$ $\qquad i = 46^\circ.7$
$e = 0.24$ $\qquad \Omega = 163.6$
$a = 0''.94$ $\qquad \lambda = 164.9$

Since 1892 the motion of the small star has carried it through an additional arc of more than 50°, giving a total arc of nearly 225° since the first measures. I have therefore thought it possible at this time to make an investigation which shall give results at least approximately correct.

The following are all the published measures of this pair that I have been able to find. Except in the grouping of the first five observations by DEMBOWSKI, the measures to 1892.40, inclusive, are taken as given by BURNHAM in the paper cited.

DATE.	θ	ρ	n	OBSERVER.	O - C.	
					Δθ	Δρ
1874.89	162°.6	1″.11	2	NEWCOMB	− 0°.6	−0″.02
74.90	174.8	1.06	1	DEMBOWSKI...	+11.6	−0.07
75.60	171.4	1.35	4	"	+11.3	+0.23
76.79	161.5	1.25	2	"	+ 5.2	+0.15
76.83	166.9	1.62	2	WALDO.......	+10.7	+0.53
76.90	160.2	1.04	2	HALL.........	+ 4.3	−0.05
77.70	155.3	1.25	8	DEMBOWSKI...	+ 2.4	+0.17
78.41	150.0	1.06	1	BURNHAM	0.0	+0.01
78.54	147.5	1.09	3	DEMBOWSKI...	− 2.0	+0.05
78.76	158.8	1.09	2, 1	HALL	+10.2	+0.05
79.50	148.3	0.90	2	BURNHAM.....	+ 2.9	−0.10
79.75	147.3	0.98	6, 5	HALL.........	+ 3.1	−0.01
80.77	137.4	1.04	1	FRISBY........	+ 1.8	+0.10
83.88	159.2		3	SEABROKE	−41.0	
85.52	116.3	1.08	3	TARRANT.....	+15.2	+0.48
85.74	100.7	0.62	1	HALL	+ 2.4	+0.03
86.78	80 ±	0.5 ±	1	HOUGH.......	− 3±	0.0 ±
87.76	56.4	0.4 ±	1	"	−10.3	−0.1 ±
89.49	36.5	0.50	4	BURNHAM.....	− 1.1	−0.04
90.54	20.5	0.54	3	"	− 1.9	−0.05
91.49	12.4	0.61	3	"	+ 1.3	−0.04
91.70	9.3	0.52	3	HALL.........	+ 0.7	−0.13
92.41	2.3	0.61	3	BURNHAM.....	+ 0.6	−0.08
92.72	358.4	0.60	3	COMSTOCK	− 0.3	−0.11
94.77	344.4	0.78	5	BARNARD.....	+ 1.9	−0.01
95.71	335.1	0.86	2	COMSTOCK....	− 0.8	+0.06
95.73	332.6	0.29±	3	SEE	− 3.2	−0.51±
96.55	333.6	0.79	3	AITKEN.......	+ 3.4	−0.02
96.64	340.9	0.48	2, 1	LEWIS........	+11.4	−0.33
96.67	330.9	0.69	3	COMSTOCK....	+ 1.6	−0.12
96.82	332.1	0.73	6	HUSSEY	+ 3.8	−0.08
97.57	322.4	0.68	3	AITKEN.......	− 0.7	−0.12
97.72	326.4	0.94	3	DOBERCK.....	+ 4.4	+0.14
97.81	328.5	0.72	5	HUSSEY	+ 7.1	−0.08
98.49	316.6	0.77	4	AITKEN.......	+ 0.2	−0.01
98.82	311.2	0.58	1	LEWIS........	− 2.7	−0.20
99.73	308.8	0.80	6	AITKEN.......	+ 2.0	+0.06
99.86	310.0	0.85	3	HUSSEY	+ 4.2	+0.11

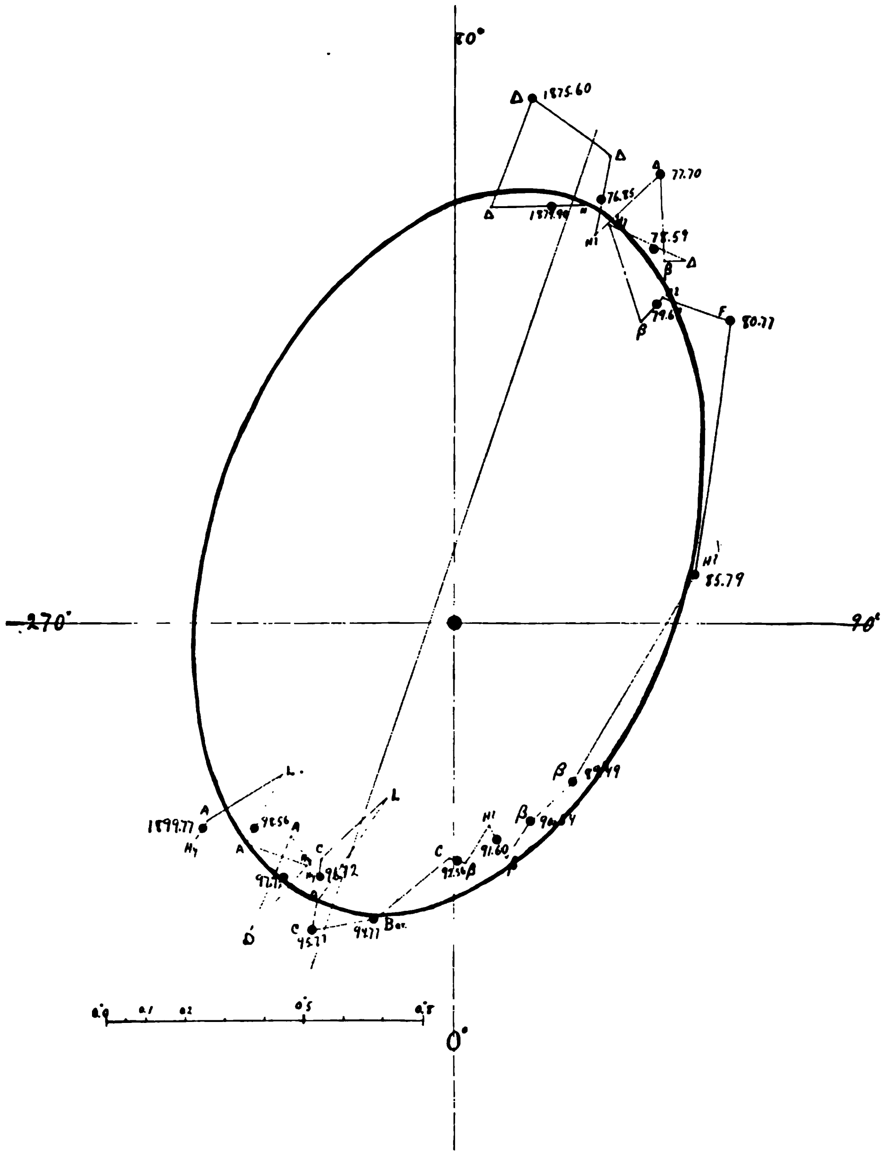
In forming annual means from these observations, the incomplete measures were disregarded; also the results obtained by WALDO, by TARRANT, and by LEWIS in 1896. The arithmetical mean of the measures in each year was then taken, all the observations being regarded as of equal weight. The resulting positions are:—

DATE.	θ	ρ	n	OBSERVER.	O-C.	
					$\Delta\theta$	$\Delta\rho$
1874.90	166°.7	1″.09	3	N-Δ.........	+3°.5	−0″.04
1875.60	171.4	1.35	4	Δ............	+11.3	+0.23
1876.85	160.8	1.14	4	Δ-Hl.........	+4.8	+0.05
1877.70	155.3	1.25	8	Δ...	+2.4	+0.17
1878.59	151.7	1.08	6, 5	Δ-Hl-β.....	+2.4	+0.04
1879.69	147.6	0.96	8, 7	β-Hl..... ..	+3.0	−0.03
1880.77	137.4	1.04	1	F............	−1.8	+0.10
1885.79	100.7	0.62	1	Hl...........	+2.4	+0.03
1889.49	36.5	0.50	4	β.....	−1.1	−0.04
1890.54	20.5	0.54	3	β............	−1.9	−0.05
1891.60	10.8	0.56	6	β-Hl.........	+1.0	−0.04
1892.56	0.4	0.61	6	β-C	0.0	−0.10
1894.77	344.4	0.78	5	Bar..........	+1.9	−0.01
1895.71	335.1	0.86	2	C............	−0.8	+0.06
1896.72	332.2	0.73	12	C-Hy-A.....	+3.2	−0.08
1897.72	326.3	0.77	11	Hy-Dob-A. .	+4.2	−0.03
1898.56	315.5	0.73	5	L-A.........	−0.4	−0.05
1899.77	309.2	0.82	9	Hy-A	+2.7	+0.08

It is apparent that no ellipse can be drawn that will represent all of these positions with satisfactory accuracy. To satisfy the law of areas even approximately, some of the distance measures must be considered to be in error. I finally decided to assume that DEMBOWSKI had overmeasured the distance considerably in the years 1875–76–77. That this assumption is allowable, will, I think, be admitted when the size of DEMBOWSKI'S telescope is considered in connection with the difference in brightness of the two components of this pair, and the discordance of recent distance measures made with instruments of large aperture. With this assumption, it became possible to draw an ellipse that would represent with reasonable accuracy the majority of the measures.

This ellipse gives by the graphical method, the following set of elements:—

$P = 45.1$ years.
$T = 1892.33$ $\qquad i = 52^{\circ}.2$
$e = 0.20$ $\qquad \Omega = 158\ .8$
$a = 0''.97$ $\qquad \lambda = 144\ .5$


180°
Δ 1875.60
Δ
Δ
77.70
76.85
Δ
1877.90
H1
78.59
β
Δ
β
79.67
F
80.77
H1
85.79
270°
90°
β
89.49
β
90.34
H1
91.60
C
92.56 β
L.
L
A
1899.77
Hy
98.56
A
A
C
97.72
96.72
D
C
95.71
94.71
B
0.0
0.1
0.2
0.5
0.8
0°

APPARENT ORBIT.

Length of major axis = 1″.96
Length of minor axis = 1 .20
Position-angle of major axis = 165°.0
Position-angle of periastron = 2 .4
Distance of star from center = 0 .18

In the diagram accompanying this paper, the small black circles represent the annual means upon which the apparent ellipse is based, and the vertices of the broken line the results obtained by the respective observers. The discordant character of the observations is manifest, as well as the general agreement with the computed positions.

In the two preceding tables the columns following the names of the observers give the residuals in angle and distance.

To test the accuracy of these elements by future observations, I have computed an ephemeris for the next five years:—

Date.	θ	ρ
1900.75	298°.2	0″.71
1901.75	288 .9	0 .68
1902.75	278 .8	0 .66
1903.75	268 .1	0 .64
1904.75	257 .1	0 .64

LICK OBSERVATORY, March 23, 1900.

NOTE.—I have just received the *Astronomische Nachrichten*, 3629, which contains Professor T. J. J. SEE's "Researches on the Orbit of *T Cygni.*" Professor SEE has in the main used the data given above, though the early observations are combined differently. He has also, apparently, used the results obtained by WALDO and TARRANT; but by some oversight has not used the measures by BARNARD in 1894, HUSSEY in 1896 and 1897, LEWIS in 1896 and 1898, DOBERCK in 1897, and AITKEN in 1897 (twenty-five observations in all). In place of the unpublished Lick Observatory measures in 1899, he has used the unpublished Naval Observatory measures for practically the same epoch.

As Professor SEE's elements differ decidedly from those given above, I copy them here together with his ephemeris, for purposes of comparison. They are:—

P = 57.25 years.
T = 1890.25
e = 0.370
a = 1″.16
i = 55°.6
☊ = 161°.4
λ = 121.8

APPARENT ORBIT.

Length of major axis = 2″.18
Length of minor axis = 1 .25
Position-angle of major axis = 165°.6
Position-angle of periastron = 24° 8
Distance of star from center = 0″.30

EPHEMERIS.

1900.70	307°.0	0″.84
1901.70	301 .3	0 .82
1902.70	294 .9	0 .81
1903.70	288 .6	0 .80
1904.70	282 .0	0 .80

From a comparison of two sets of ephemerides, it is apparent that the measures of the next two or three years will show which orbit is nearer the truth.

April 5, 1900.

THE DEVELOPMENT OF ASTRONOMY IN AMERICA.

Reprinted from *Nature* (London), April 12, 1900.

Sixty years ago the United States had scarcely a single observatory properly equipped for the pursuit of astronomical studies. To-day that country is possessed of the finest observatories in the world, manned by observers of the greatest skill, who devote themselves untiringly to the advancement of the oldest of the sciences.

The success of the American astronomers during this short period has been remarkable. To them we owe important discoveries and precious records in nearly every branch of theoretical and practical astronomy, and especially of late years in the department of astronomical physics. It is impossible here to recount the whole fruits of their labors, but it is worth while to recall a few of the results which we owe to their industry.

The first striking discovery in America was that of *Hyperion*, the seventh satellite of *Saturn*, by G. P. BOND, in 1848. In the same line of work, HALL was rewarded in 1877 by the discovery of the tiny satellites of *Mars*, and more recently BARNARD astonished the world by his detection of the fifth satellite of *Jupiter*, while PICKERING claims to have established the existence of a ninth satellite of *Saturn*. In planetary studies generally, the Americans have been well to the front, and we have seen the unusual spectacle of a powerful refractor primarily devoted with marked success, by Mr. LOWELL, to the delineation of the surfaces of our nearest planetary neighbors. Numerous measurements of the dimensions of the various members of the solar system have also been made, and the theory of their motions has been greatly advanced, notably by the well-known investigations of NEWCOMB.

Cometary astronomy has likewise benefited by their zeal, many new discoveries having been made, and the orbits of a large number calculated; in this branch the Americans are now more active than ever, no less than six of the seven new comets discovered in 1898 being to their credit. Important investigations relating to meteorites and the orbits of meteor swarms have also been carried out, and the name of Prof. H. A. NEWTON will always be associated with this department of astronomical research.

Sidereal astronomy has been enriched by numerous star catalogues, and double-star observation has been brought to a high standard of perfection by the assiduous efforts of BURNHAM, HALL, and SEE; while PICKERING'S "Harvard Photometry" has given us an invaluable record of the magnitudes of thousands of the brighter stars. The study of variable stars has also been very productive, our most important catalogue of these objects being due to CHANDLER, while a unique atlas of variable stars is in course of publication by Prof. HAGEN; here, as in many other directions, Prof. PICKERING'S ingenuity has been displayed, and he has shown among other things how variables of short period can be readily detected, and the changes studied, by photographic means.

Our catalogues of nebulæ discovered since the time of the HERSCHELS include a large number of entries to the credit of American observers, LEWIS SWIFT having specially distinguished himself in this field of work.

Notable work has also been done in the domain of solar physics. YOUNG'S observations of the chromospheric spectrum have only been surpassed by the most recent eclipse photographs, and Prof. HALE was the first to initiate a regular photographic record of the forms of the chromosphere and prominences. Quite recently, the great telescope of the Yerkes Observatory has been used for a very detailed examination of the spectrum of the chromosphere, and even the most minute structure of the carbon flutings in the green has been successfully observed. To Prof. ROWLAND we owe a great catalogue of close upon twenty thousand of the Fraunhofer lines, the positions of which are stated with a degree of accuracy never before attempted; and physicists and astronomers throughout the world are indebted to this observer for the magnificent diffraction gratings which his skill has placed at their disposal. By the invention of the bolometer, LANGLEY has opened up a new region of the spectrum, and has made numerous important observations by its aid. At the present time a committee of American astronomers is organizing the work to be undertaken during the total eclipse of the Sun next May, and from a preliminary report which has been issued we gather that they are fully alive to the opportunities which such an event affords.

Astronomy owes an immense debt to photography, and it should not be forgotten that the first photographic impression of a star was obtained on the other side of the Atlantic, by Prof. BOND, in 1850. Among those who early recognized the possibilities of astronomical photography was RUTHERFURD, of New York, who obtained numerous pictures of the Sun, Moon, and stars in the early 'seventies, the full value of which has only lately begun to appear. It was there also that Dr. DRAPER, in 1872, secured the first photograph of a stellar spectrum which revealed anything relating to the composition of a star, and that BARNARD, in 1892, made the first discovery of a comet by the aid of the camera.

The story, however, by no means ends with this pioneer work; celestial photography has been pursued with the greatest success in every direction, notable among the results being BARNARD'S photographic delineation of comets, nebulæ, and the Milky Way, and the magnificent spectroscopic work of the Henry Draper Memorial carried on by Prof. PICKERING at Harvard College.

Within the last few years the energetic director of the Harvard College Observatory has been enabled to extend his operations by the erection of a well-equipped observatory in the clear air of Arequipa, Peru, spectroscopic and other data on a uniform plan for the whole celestial vault being thus secured. Prof. PICKERING has, in fact, developed the photographic side of his work into a wonderful detective force, so perfectly organized that no new star of reasonable brightness can escape detection, and no important change in a known star go unrecorded. The munificent gifts to the Harvard Observatory have thus, in Prof. PICKERING'S hands, been put to the best possible uses.

The work of the Lick Observatory is also largely photographic. Here, the great refractor has been employed with the greatest success by Prof. CAMPBELL in photographing the spectra of nebulæ and bright line stars. More recently special attention has been given to the photographic determination of stellar velocities in the line of sight, with the result that a dozen or so of spectroscopic binaries have already been detected, *Polaris* and *Capella* being among the most interesting systems thus recognized. Quite recently marvelous results have been obtained by Prof. KEELER in photographing the forms of nebulæ with the Crossley reflector. The director's report for the year ending September 1, 1899, indicates a remarkable state of activity among the comparatively small staff of this observatory. The success of these observers is doubtless in some measure due to the wisdom displayed in the limitations which they have set to their work. A well-defined programme, and concentration upon it, appears to be the policy adopted, and the truly scientific spirit which controls their investigations is exhibited by the following remarks from Prof. KEELER's last report: "Comets which are bright enough to be easily seen at the leading observatories receive only occasional attention, while comets which, by reason of their faintness or unfavorable position, are difficult of observation, are followed as closely as possible. . . . The Lick Observatory makes the most of its natural advantages; and extended theoretical researches, which can be made as well in a city as at a fine observing-station, do not form part of our general plan." In this way the output of useful observations is greatly increased, and the co-ordination of different facts can be carried on by workers generally. The same spirit prevails at Harvard Observatory, where "precedence has been given to physical work, since less attention is paid to such work elsewhere," and the photographic records there accumulated have been placed at the service of any one properly qualified to discuss them.

The Yerkes telescope, in the hands of BURNHAM, BARNARD, and HALE, has already been very productive. One of the most important pieces of work undertaken here is the photographic registration of the spectra of the *Piscian* (III *b*) stars; and the wealth of detail recorded in such difficult objects is truly remarkable.

But it is by no means only in observatories furnished with giant telescopes that astronomical science has been advanced. Admirable work has also been done in unpretentious establishments, and, indeed, with no observatories at all. GOULD'S investigation of the Milky Way and the distribution of stars is a case in point, and, to take another example, a vast amount of energy has been expended in perfecting the *American Ephemeris* and *Nautical Almanac*. CHANDLER'S masterly investigations of the variations of terrestrial latitude also demand separate mention.

Terrestrial researches bearing on astronomical phenomena have not been neglected. NEWCOMB and MICHELSON'S determinations of the velocity of light are classical examples, and among more recent work reference may be made to ROWLAND'S determinations of the origins of a vast number of Fraunhofer lines, and to HUMPHREY'S and MÖHLER'S investigations of the displacement of spectrum lines due to pressure.

It will be seen, even from this incomplete statement, that the output of astronomical work in America has been very great, and there is every indication that it will go on increasing. The rapid development is doubtless due to various causes, not least among them being the unstinted support given by private benefactors. The American astronomers undoubtedly also owe a great debt to their opticians and engineers, the Lick and Yerkes refractors, with their apertures of thirty-six and forty inches respectively, being the crowning triumphs of the instrument-makers. Messrs. ALVAN CLARK'S telescopic object-glasses have long been justly held in high estimation all over the world, and the skill of Messrs. WARNER & SWASEY has been fully equal to the task of successfully mounting their mammoth productions.

Some of the success of the Americans may perhaps be attributed to their wise selection of sites for their instruments, when they have been free to exercise their judgment. The Lick Observatory, at an elevation of 4,000 feet, is favored with exceptionally good atmospheric conditions, and the sites of the Yerkes and various other observatories were only decided upon after very careful trials.

Instrumental equipment and good climate, however, are not the only requisites for a successful observatory. Much depends upon the men at the little ends of the telescope tubes, and, we may add, upon the men at their desks or in their laboratories, who bring their minds to bear upon the explanation or utilization of the phenomena observed, besides suggesting further observations. The training of astronomers is therefore of as much importance as the provision of instruments. Fortunately, America can boast of unparalleled facilities for this necessary training. Students' observatories abound, and in many cases instruction of the most advanced character is obtainable. Of elementary instruction it is scarcely necessary to speak; but American students are to be congratulated if the teaching generally is on such enlightened lines as those indicated in Miss BYRD'S "Laboratory Manual of Astronomy," and Prof. TODD'S "New Astronomy." A most valuable paper, by Prof. E. S. HOLDEN, on the teaching of astronomy in primary and secondary schools and in the university has recently been published.* During the early years of a child's school life, the lessons must necessarily be simple; and Prof. HOLDEN gives an extremely suggestive sketch of the methods which should be followed, bearing in mind that "the main point is to open the eyes and mind, and the Sun and stars are convenient for the purpose." To the teachers of astronomy in secondary schools Prof. HOLDEN also gives many valuable hints. Here astronomy is to be regarded as an "information study," as well as an educative one, and suggestions as to simple apparatus to facilitate the teaching are given.

From our present point of view, however, the most interesting part of Prof. HOLDEN'S paper is that referring to the courses of instruction in astronomy offered by some of the American universities and colleges. Particulars are here given of the instruction carried on in fifteen institutions, and they illustrate in the most satisfactory manner the advantages enjoyed by the American student who wishes to acquire an extended knowledge of the subject. The courses are in several cases remarkably comprehensive, and in five of them astrophysics takes an important place in the curriculum. In every case there appears to be an adequate supply of instruments and observatories, and for students desiring to specialize there are abundant opportunities of entering even the best observatories.

The course of the University of Chicago is perhaps the most complete, but the syllabus is too long for quotation; suffice it to say that it includes every department of theoretical and practical astronomy, the astrophysical instruction being carried on at the Yerkes Observatory by the distinguished staff of resident professors and observers. The director of the Yerkes Observatory some time ago made the following statement as to the relation of that establishment to the work of students: "After completing the necessary preliminary work at Chicago, students who desire to devote special attention to observational astronomy or to astrophysics are admitted to the Yerkes Observatory at Lake Geneva, where they are given every possible facility. In addition to pursuing the courses of instruction enumerated in the *Annual Register* of the University of Chicago, students at the observatory may take part in the regular work of research. As soon as they have had sufficient preliminary training, they are encouraged to undertake original investigations of their own." From other notices we gather that this privilege is not restricted to students from Chicago.

---

* "Report of the Commissioner of Education, 1897-98." Vol. I, p. 869. (Washington, 1899.)

At the University of California also an admirable course of astronomy is offered, one item of which may be quoted as illustrating the attention given to practical work: "4 A. Practical astronomy. Lectures and observatory work. Navigation and nautical astronomy. Practical work in the observatory. Six hours observatory, first half. Three hours lecture and six hours observatory, second half."

The University possesses an excellently equipped students' observatory, in addition to the world-famous establishment on Mount Hamilton. Graduates of the University, or indeed of other universities of equal standing, are received at the Lick Observatory to pursue a higher course of instruction in astronomy; every facility consistent with the scientific work of the establishment will be given them, and they will usually be assigned as assistants to some of the astronomers. An illustration of the bond between the greater and lesser establishments is afforded by the recent computation at the students' observatory of the elements of a comet from observations telegraphed by the astronomers at Lick. (*Pub. Ast. Soc. Pac.*, Vol. XI, No. 70, p. 190.)

From the information which Prof. HOLDEN has collected, we gather that special students of promise have also the privilege of entering into the regular work of the observatories at Harvard College, and the Universities of Yale, Michigan, Virginia, Wisconsin, and Pennsylvania.

The special value to the student of this association with the staff of an observatory is admirably stated by Prof. HOLDEN in a report on the Lick Observatory, from which he makes the following quotation: "No institution in the world is better fitted to give such instruction, and there is a special impetus to be gained in an observatory which is regularly pursuing work of discovery and research. The student comes directly into the current, and learns far more by observation of the methods of others than by the study of text-books. He can take part in the regular work of the observatory also." This happy arrangement is not only beneficial to the student. Prof. HOLDEN further remarks: "It is a great advantage to the University as a whole to count among its members a considerable number of active and ambitious young men who are able to work with some independence to advance science, and not merely to acquire what is already known. They set a standard of scholarship to all the undergraduates. Such students can take a useful part in the actual observations of every day as assistants, and after some practice they become valuable aids in our work of computation and observation, and supplement the permanent force of the observatory in an important degree."

No wonder that with advantages like these there is an adequate supply of highly-trained young astronomers capable of fully developing the great resources which the scientific spirit of wealthy Americans has placed at their disposal. It appears to us that it is precisely for want of opportunities for securing the necessary technical training to future observers that the astronomical development of our own country proceeds less rapidly than that of America. While it is possible to obtain a certain amount of tuition in spherical astronomy, and here and there a modicum of practical instruction in the older branches of the subject, facilities for the study of astrophysics are almost completely lacking, and it is a deplorable fact that the universities are especially deficient in this respect.

Under the Science and Art Department, a general study of astronomy is encouraged, but the subject is incorporated with a variety of other subjects under the comprehensive title of Physiography, and no separate certificate for astronomy is granted.

At the universities, astronomical teaching appears to remain in much the same position as the teaching of chemistry and physics before the introduction of practical work in those subjects, the prevailing idea apparently being that if a mathematician can be placed at the head of affairs in an observatory, it matters little who makes the actual observations or whether observations are made or not. There can be little doubt that means exist for establishing schools of astronomy comparable with those which have arisen for other branches of science, and we sincerely hope that the need for serious attention to practical teaching in astronomy will soon be recognized.

So far as we know, there is only one institution in Great Britain where any attempt is made to give practical instruction in astronomical physics, and even in this case the greater part of the instruction is necessarily of a somewhat elementary character, in consequence of the small amount of time available for the subject.

It is a natural consequence of our inadequate provision for technical education in astronomy — more particularly in the newer branches — that vacancies in our observatories must be filled by observers who have still to make practical acquaintance with the work expected of them. Much loss of time and apparent inactivity is the result.

It may be urged that benefactors of the science of astronomy are less numerous here than in America, but the generous gifts of Dr. F. McCLEAN to Cambridge University and the Cape Observatory, and of Sir HENRY THOMPSON to the Royal Observatory, Greenwich, remind us that they are not wholly wanting. Besides, there are already numerous observatories scattered throughout the country which might be made more productive by putting them in the hands of observers who have received adequate training. Public interest in astronomy is by no means absent, and British observatories would, perhaps, receive a much increased measure of support if it were not for the possible impression that the best work can only be done in America, and that instruments of the largest size are alone useful.

A HANDBOOK OF ASTRONOMICAL INSTRUMENTS.

Handbuch der Astronomischen Instrumentenkunde. Von Dr. L. AMBRONN, Professor an der Universität und Observator an der königl. Sternwarte zu Göttingen. Mit 1185 in den Text gedruckten Figuren. Berlin, Verlag von JULIUS SPRINGER, 1899. (Price, $15.00.)

Dr. AMBRONN's two large volumes form an encyclopædia of astronomical instruments in which the whole of the instrument-maker's art, from the shaping of the slot in a screw-head to the construction of a modern great equatorial, is clearly described and illustrated with an abundance of excellent figures. The work is not wholly descriptive, however, since theoretical discussions of many subjects, such as the determination of the periodic errors of screws and of the graduation errors of circles, are freely introduced.

The first volume, containing five hundred pages, is devoted to accessory apparatus, clocks, and the separate parts of instruments. We find here an account of screws, levels, artificial horizons, axes and circles, mirrors, eye-pieces, etc. An interesting feature of the book is that the descriptions are not confined to instruments of the present day. Older forms of instruments, progenitors of modern types, are treated at some length, and illustrated when the historical development of the subject makes their consideration desirable. Thus we find, in the first volume, an account of various early applications of the plumb-line and of early forms of clocks.

The second volume, containing 776 pages, is devoted to complete instruments of every kind—meridian-circles, universal instruments, chronographs, equatorials, etc., but it is impossible to give here an adequate idea of the contents of this very complete treatise.

Dr. AMBRONN'S volumes are, on the whole, a manual of German practice; but national bias in such a work is inevitable, and in this case is the less to be regretted, since the Germans have always excelled in the art of instrument-making. Still, readers of other nationalities will notice omissions which they may be inclined to regard as important. No American, perhaps no Englishman, would write a treatise on screws in which ROWLAND'S method of making screws of precision, as described in the *Encyclopædia Britannica*, is not mentioned. In the chapter on clocks the name of DENT does not occur. Sir E. BECKETT'S gravity escapement, which is so widely used in England and America, and which is probably the best of its kind, is not described or even referred to. On the other hand, an English or American writer would certainly overlook many of the escapements described and illustrated in the same chapter, as they are hardly used outside of Germany.

On reading the author's comments on different forms of instruments, in which complicated devices for manipulation or adjustment are almost invariably spoken of in terms of approbation, one cannot avoid the impression that simplicity and rudeness are too generally regarded as synonymous, while elaborateness is regarded as essential to the highest precision. This attitude is noticeable in the comments on American instruments, of which, it seems to the reviewer, the author has failed to grasp the characteristic features. These are, briefly, the care bestowed on essentials, and the indifference with which minor details are treated. One can imagine the disfavor with which the author would view the rough-looking yet effective instruments of the Harvard College Observatory. The lover of instruments may like to see his apparatus beautiful and perfectly finished in all its parts, but he should be willing to concede that perfection of finish is not essential to performance. There are some instrument-makers, like the late Mr. DENT, the celebrated English clock-maker, who finish the non-essential parts of their instruments with the greatest care, in deference to the wishes of their patrons, though personally holding the opinion that in so doing they are merely wasting time. In America the rough-looking instrument is not generally objected to, if its proportions are correct, and if it works well.

Appliances for the adjustment and manipulation of instruments do not always tend to increase the accuracy of observation, and sometimes are even prejudicial to it. For instance, the clamp and tangent-screw ordinarily attached to graduated circles are not used by skilled observers with the micrometer. The elaborate mechanical adjustments on some forms of level-triers are, possibly, conveniences, but they do not (as is implied by the remarks on p. 62) add anything to the precision of the observations. The essential feature of this instrument is stability, including freedom from the effect of temperature changes.

It is true that (as stated on p. 1049) the Americans have not advanced beyond the single-pen form of chronograph. Their preference for this form does not, however, arise from prejudice or non-progressiveness, but from the consideration that even with a single pen the record is still more precise than the observation itself. The use of a double set of prickers, by which the record of an observation can be read to a few thousandths of a second, would seem to be as unnecessary as seven-place logarithms for computing the time of sunrise.

If the details of many American instruments might be more carefully fitted and finished, it may be said of many German instruments that the harmony of the general design has been to some extent lost sight of in the attention paid to the component parts. The weight of metal is often in the wrong place, and the instrument has an awkward appearance. An exception should be made here of the graceful instruments of REPSOLD. In the judgment of the reviewer, there is no small equatorial among the many illustrated in Dr. AMBRONN'S book which so fully satisfies the sense of mechanical proportion as the WARNER & SWASEY mounting on page 1156.

The mounting of a modern great equatorial is really a problem in engineering, and if one may venture a criticism of the fine large equatorials of recent European construction, it is that they have been treated rather from the standpoint of the instrument-maker. With respect to the numerous attachments of large equatorials, it is certain that, in the case of the Lick telescope, at least, experience has shown some of them to be unnecessary; and this is a point of no small importance, since these attachments are often very expensive. The quick motions for operating the Lick telescope from the top of the pier are indispensable, but the slow motions at the same place are never used, and, since they somewhat increase the friction of the polar axis, they could well be dispensed with. The microscope and reflectors for reading the finely divided hour-circle from the eye-end have never once been used, and the declination microscopes at the eye-end very seldom, so that these attachments have been removed. In fact, on duly considering the matter, we find that the fine circles of a great equatorial have only one use — to perfect the adjustment of the polar axis,—and provision for reading them from the head of the pier is sufficient for this, and therefore for every purpose.

By far the least satisfactory chapter in the book is the one on spectroscopic apparatus, which is compiled, not very judiciously, from various sources. The instruments and appliances to which the greater part of the space is devoted are old and of small efficiency, while really efficient instruments, for which all the conditions of use have been carefully studied, are passed over lightly, or only referred to in foot-notes. It is true that the former instruments might have been introduced for their historical interest, but the reader is left to suppose that they are still valuable for purposes of research. The Potsdam spectrograph, which has only recently been superseded by more efficient instruments, has about a page. It is a pity that the MILLS spectrograph of the Lick Observatory, Professor VOGEL'S new Potsdam spectrograph, or Dr. GILL'S spectrograph for the Cape Observatory, could not have been included; but for this the book was published just a little too soon.

A brief statement of the theory of resolving power, as developed by Lord RAYLEIGH, would have been very useful as a guiding principle, which is totally lacking in the chapter, and would have shown at once the practical uselessness of some of the forms of spectroscopes described.

The chapter on photometers, on the other hand, is especially valuable. Here the different forms of photometers used in astrophysical research are brought together in a most convenient form for reference.

Occasional mistakes can be found. Fig. 1160, which purports to represent the moving floor of the Lick Observatory, is a design which was proposed, but not adopted; but such mistakes as this would naturally be made by one who is not personally familiar with all the instruments described, and they are few in number. It is hardly necessary to say that Dr. AMBRONN'S valuable book should be found in the library of every observatory.

J. E. KEELER.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1900.

By MALCOLM MCNEILL.

JULY.

The Earth is in aphelion at 4 A. M., July 2d, P. S. T.

Mercury is an evening star throughout the month, and comes to greatest east elongation on the morning of July 4th. During the first half of the month it will set an hour or more after sunset. After the middle of the month, it will be too close to the Sun to be seen, and it reaches conjunction with the Sun on the night of July 31st-August 1st. The present elongation, 26°, is greater than that in March, by 8°, as it comes very near the time when the planet is in aphelion, July 13th, while that in March was about the same interval from perihelion. The fact that at the July elongation the planet is south of the Sun, while the reverse was true in March, makes a considerable offset in the interval between the setting of the Sun and the planet; but, on the whole, the July elongation affords the best opportunity of the year for evening observation.

Venus passes inferior conjunction with the Sun on the morning of July 8th, and changes from an evening to a morning star. It is still moving westward among the stars, and this motion, combined with the eastward motion of the Sun, causes a rapid separation of the bodies, so that by July 20th the planet rises more than an hour before sunrise, and about twice that on July 31st, and it will be an easy object to see. On July 29th the planet begins to move eastward again among the stars.

Mars rises earlier, and has begun to increase in brightness. It moves 23° eastward among the stars in *Taurus*, and on July 10th passes about 5° north of the first-magnitude red star *Aldebaran*.

Jupiter remains above the horizon until after midnight. It moves westward about 1° until July 29 in the constellation *Scorpio* near the third-magnitude star *β Scorpii*, the time of nearest approach being July 5th, when the planet is 15′ south of the star.

Saturn is in fine position for observation, being above the horizon until long after midnight. It moves westward about 2° in the constellation *Sagittarius*, north and west of the handle of the Dipper. On the night of July 10th, it will again be occulted by the Moon, the occultation occurring before midnight in the Eastern States, and earlier in the evening in the Western States.

Uranus is still near *Jupiter* in *Scorpio*, about 7° east.

Neptune moves about 1° east near the border line of *Gemini* and *Taurus*.

AUGUST.

Mercury passes inferior conjunction at the beginning of the month, and moves rapidly out toward greatest west elongation, which it reaches on August 19th. After August 10th, it rises more than an hour before sunrise, and may be seen in the early morning twilight.

Venus is morning star. It moves eastward among the stars about 16°, while the Sun moves nearly double that amount; so the distance between the two is increased about 12°, and the interval between the rising of the planet and sunrise increases to about three and one half hours. The planet will be very brilliant all through the month, reaching the maximum on August 14th, and may be seen by daylight with the naked eye.

Mars rises half an hour earlier than during July. It moves about 22° eastward during the month, from the constellation *Taurus* into *Gemini*, and at the end of the month is a little west of *Castor and Pollux*, the three making nearly a right-angled triangle, with the right angle at *Pollux*, the southern star.

Jupiter remains in good position for observation in *Scorpio*, not setting until late in the evening. It resumes its eastward journey among the stars at the end of July, and during August moves about 2°. It again passes the third-magnitude star *β Scorpii* on August 22d, the southward distance of the planet being 26′, nearly twice as great as it was at the July approach. Its eastward path will be in general about half a degree south of the line it pursued while retrograding.

Saturn remains in *Sagittarius*, moving westward about 1°, and is above the horizon until nearly morning. As the rings are now at about their maximum opening, the planet presents perhaps its finest view in the telescope.

Uranus is still in about the same position, nearly stationary in *Scorpio*. The motion of *Jupiter* is bringing it back toward *Uranus*, and at the end of the month the latter is about 6° east of the former.

Neptune moves about 1° east on the border of *Taurus* and *Gemini*.

JULY-AUGUST, 1900.

PHASES OF THE MOON, P. S. T.

First Quarter . . .	July 4,	$4^h 14^m$ P. M.
Full Moon	July 12,	5 22 A. M.
Last Quarter . . .	July 18,	9 31 P. M.
New Moon	July 26,	5 43 A. M.
First Quarter . . .	Aug. 3,	8 46 A. M.
Full Moon	Aug. 10,	1 30 P. M.
Last Quarter . . .	Aug. 17,	3 46 A. M.
New Moon	Aug. 24,	7 53 P. M.

THE SUN.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
July 1,	$6^h 40^m$	+ 23° 8′	$4^h 40^m$ A. M.	12^h 4^m P. M.	$7^h 28^m$ P. M.
11,	7 21	+ 22 9	4 45	12 5	7 25
21,	8 1	+ 20 32	4 53	12 6	7 19
Aug. 1,	8 45	+ 18 5	5 3	12 6	7 9
11,	9 23	+ 15 21	5 11	12 5	6 59
21,	10 0	+ 12 12	5 21	12 3	6 45
31,	10 37	+ 8 43	5 30	noon	6 30

Mercury.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
July 1,	$8^h 30^m$	$+ 19° 31'$	$6^h 44^m$ A.M.	$1^h 53^m$ P.M.	$9^h 2^m$ P.M.
11,	9 1	+ 15 20	6 52	1 45	8 38
21,	9 5	+ 12 40	6 25	1 9	7 53
Aug. 1,	8 38	+ 13 25	5 14	noon	6 46
11,	8 21	+ 16 18	4 7	11 4 A.M.	6 1
21,	8 48	+ 17 33	3 49	10 50	5 51
31,	9 52	+ 14 30	4 25	11 15	6 5

Venus.

July 1,	7 25	+ 19 18	5 40 A.M.	12 48 P.M.	7 56 P.M.
11,	6 58	+ 17 54	4 40	11 43 A.M.	6 46
21,	6 37	+ 17 5	3 43	10 42	5 41
Aug. 1,	6 32	+ 17 0	2 54	9 53	4 52
11,	6 43	+ 17 22	2 25	9 25	4 25
21,	7 5	+ 17 43	2 7	9 8	4 9
31,	7 36	+ 17 42	1 58	8 59	4 0

Mars.

July 1,	4 4	+ 20 32	2 14 A.M.	9 27 A.M.	4 40 P.M.
11,	4 33	+ 21 51	2 0	9 18	4 36
21,	5 3	+ 22 49	1 46	9 8	4 30
Aug. 1,	5 35	+ 23 30	1 33	8 58	4 23
11,	6 4	+ 23 45	1 19	8 46	4 13
21,	6 33	+ 23 41	1 9	8 35	4 1
31,	7 1	+ 23 18	1 0	8 24	3 48

Jupiter.

July 1,	16 1	− 19 49	4 33 P.M.	9 23 P.M.	2 13 A.M.
Aug. 1,	15 56	− 19 43	2 26	7 16	12 6
Sept. 1,	16 3	− 20 10	12 34	5 22	10 10 P.M.

Saturn.

July 1,	18 5	− 22 28	6 48 P.M.	11 27 P.M.	4 6 A.M.
Aug. 1,	17 57	− 22 32	4 37	9 16	1 55
Sept. 1,	17 53	− 22 36	2 32	7 11 P.M.	11 50 P.M.

Uranus.

July 1,	16 31	− 21 49	5 10 P.M.	9 52 P.M.	2 34 A.M.
Aug. 1,	16 27	− 21 43	3 6	7 48	12 30
Sept. 1,	16 27	− 21 43	1 4	5 46	10 28 P.M.

NEPTUNE.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
July 1,	$5^h 48^m$	$+ 22° 14'$	$3^h 52^m$ A.M.	$11^h 12^m$ A.M.	$6^h 32^m$ P.M.
Aug. 1,	5 52	+ 22 14	1 54	9 14	4 34
Sept 1,	5 56	+ 22 14	11 55 P.M.	7 15	2 35

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

II, R,	July 1,	$7^h 41^m$	P.M.	II, D,	Aug. 2,	$5^h 3^m$	P.M.
I, R,	1,	11 33		II, R,	2,	7 31	
I, R.	3,	6 2		I, R,	2,	8 9	
III, D,	6,	6 59		II, D,	9,	7 41	
III, R,	6,	8 50		I, R,	9,	10 4	
II, R,	8,	10 18		II, R,	9,	10 9	
I, R,	9,	1 28	A.M.	II, D,	16,	10 18	
I, R,	10,	7 56	P.M.	II, R,	17,	12 47	A.M.
III, D,	13,	10 57		III, D,	18,	6 50	P.M.
III, R,	14,	12 50	A.M.	III, R,	18,	8 50	
II, R,	16,	12 56		I, R.	25,	8 22	
I, R,	17,	9 51	P.M.	II, R,	27,	4 43	
I, R,	24,	11 46					
II, R,	26,	4 53					
I, R,	26,	6 14					

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DISCOVERY OF A NEW ASTEROID, 1899 FD, WITH THE CROSSLEY REFLECTOR.

The region of HINDS's variable nebula in *Taurus* was photographed with the Crossley reflector on the night of December 6, 1899, with an exposure of four hours, and on the negative, when it was examined the next morning, there was found a very fine faint line, which was recognized as the trail of an asteroid.

Owing to a defect in the film, the position of the asteroid could not be determined accurately on the first plate, and another photograph was made on the night of December 9th. The next observation was made on December 26th. From these two positions, circular elements were computed by Mr. CODDINGTON. These elements represented the motion of the asteroid with much accuracy, owing to the fact, subsequently discovered, that the eccentricity of the orbit is very small.

As the telescope was constantly in use for other purposes, a third observation was not obtained until the night of January 19th. On this night the 36-inch refractor was available for visual observations, and a search was made for the asteroid with the aid of the photograph just taken. It was, however, not certainly visible, and its magnitude was taken to be 17.

The following positions were deduced from measurements of the plates by Mr. CODDINGTON and Mr. PALMER :

1899–00.	Mt. H. Mean Time.	App. R. A.	App. Dec.
Dec. 9.	$9^h\ 29^m\ 36^s$	$4^h\ 13^m\ 52^s.58$	$+19^\circ\ 14'\ 51''.9$
26.	8 11 22	4 1 11.01	+19 2 22.2
Jan. 19.	7 53 35	3 54 49.32	+19 15 30.7

From these observations the following elliptic elements were computed by Mr. PALMER, and independently by Mr. PHIPPS, of the Students' Observatory, Berkeley.

---

* Lick Astronomical Department of the University of California.

Epoch, 1900 Jan. 0.0, Berlin M. T.

$M = 296^\circ\ 42'\ 7''.9$ $\phi = 1^\circ\ 13'\ 23''.3$
$\omega = 46\ \ 39\ \ 31\ .5$ $\mu = 736''.622$
$\Omega = 92\ \ 44\ \ 39\ .0$ $\log a = 0\,455174$
$i = 3\ \ 13\ \ 15\ .8$ $m_0 = 16.7$ $g = 13.1$

The values of M and ω are subject to considerable uncertainty, on account of the small eccentricity. The asteroid is the smallest that has yet been found. J. E. K.

NEW DOUBLE STARS.

My search for new double stars has resulted in the finding of thirty-seven new pairs (all under 5″) in the first four months of the present year. Twenty-five of these have distances of less than 2″, thirteen are under 1″, and five of them are very close. In general the 12-inch has been used for this work, but on two or three nights when the seeing did not admit of the use of high powers, some sweeping was done with the 36-inch telescope.

A few of the pairs found possess sufficient interest to warrant their publication here in advance of the complete list. These are:—

A. G. Cambridge 2997.

$6^h\ 3^m\ 22^s\ +29^\circ\ 15'$.

1900.201	343°.6	0″.58	7.5 – 8.5	3	12
.204	344 .0	0 .58	7.5 – 9.0	3	12
.209	348 .3	0 .46	7.5 – 8.5	3	36
.291	342 .4	0 .49	7.5 – 8.5	3	36
1900.23	344°.6	0″.53	7.5 – 8.6		

Found with the 12-inch on March 14th, while looking for the following star:—

A. G. Cambridge 3025.

$6^h\ 5^m\ 20^s\ +28^\circ\ 47'$.

1900.190	284°.8	0″.43	9.0 – 9.5	3	36
.193	288 .4	0 .52	8.7 – 9.3	3	36
.209	293 .3	0 .52	8.5 – 9.2	3	36
1900.20	288°.8	0″.49	8.7 – 9.3		

Found with the 36-inch on March 10th.

SD −3° 1576.
$6^h\ 40^m\ 19^s$ −3° 52′.

AB.

1900.127	235°.4	0″.86	9.0 − 12.0	4	12
.152	238 .2	1 .03	8.5 − 13.0	4	36
.245	233 .6	1 .01	9.0 − 12.5	3	36
1900.17	235°.7	0″.97	8.8 − 12.5		

AC.

1900.152	320°.0	4″.94	− 14.5	4	36
.245	320 .6	5 .03	− 14.5	3	36
1900.20	320°.3	4″.98	− 14.5		

The close pair was found with the 12-inch on February 15th, and the third star added with the large telescope.

SD − 3° 1603.
6^h − 3°

1900.127	147°.2	4″.07	7.5 − 8.2	3	12
.130	145 .4	4 .02	7.5 − 8.2	2	12
.152	147 .8	4 .21	7.8 − 8.4	4	36
1900.14	146°.8	4″.10	7.6 − 8.3		

This star is interesting mainly because it has not been seen before as a double star. This may be due merely to chance, or the pair may have been much closer in the early part of the century when this region of the sky was systematically examined by STRUVE and HERSCHEL.

DM + 72° 550.
$11^h\ 48^m\ 44^s$ + 72° 29′.

1900.245	205°.5	0″.26	7.5 − 8.0	3	36
.346	210 .5	0 .30	7.0 − 8.0	3	36
1900.29	208° 0	0″.28	7.2 − 8.0		

Found with the 36-inch on March 30th, while measuring β 794, which is 2° farther north. R. G. AITKEN.

A REMARKABLE METEOR TRAIN.

A remarkable meteor train was observed at Mt. Hamilton on the night of March 29th. The meteor itself was seen in the east at about $9^h\ 55^m$ by two of the ladies at the Lick Observatory, who described it as very brilliant and surrounded by a bright glow, or halo. It had very little motion, and lasted an unusually long time.

On disappearing, the meteor left a very bright train, which at $10^h 30^m$ looked like the tail of a bright comet. It drifted slowly westward, passing just above the pole-star, and disappeared in the northwest at about $11^h 30^m$. Unfortunately, all the spectroscopes suitable for observing the bright cloud as it passed across the sky were dismounted, in preparation for the solar eclipse.

According to notices in the newspapers, the meteor was observed at least as far eastward as Utah. J. E. K.

MEASURES OF TWO DOUBLE STARS—PROBABLY NEW.

B.D. + 13° 3607					Seeing.
1900.208	3°.8	3″.46	8.8	10.	3
.285	3 .8	3 .32	8.8	10.5	2—3
1900.246	3°.8	3″.39	8.8	10.2	
B.D. + 14° 3502					
1900.208	149°.0	1″.90	8.5	8.6	3
.285	148 .7	1 .86	8.8	9.0	2—3
1900.246	148°.8	1″.88	8.6	8.8	

There is a 13th-magnitude star at 51°.4, 14″.9.

B.D. + 13° 3607 was used as the comparison star for an observation of Comet *e* 1899 on December 6th, when it was noticed to be double. Later in setting for it, B.D. + 14° 3502 accidentally came into the field and was noticed to be double also.

The above observations were made with the 36-inch refractor using a power of 520. These stars could not be identified from any of the principal catalogues. C. D. PERRINE.

MT. HAMILTON, April 17, 1900.

PUBLICATIONS OF THE LICK OBSERVATORY, VOL. IV.

The complete edition of Volume IV of the *Lick Observatory Publications* has been received from the State Printing Office, and will be distributed as soon as practicable. The volume contains meridian-circle observations of 310 standard stars, with a very complete discussion of results, by Professor R. H. TUCKER. Of these stars, 157 are from the *American Ephemeris*, the *Connais-*

sance des Temps, and the *Berliner Jahrbuch*, and 153 are from the *Berliner Jahrbuch.*

Considerable space is devoted to a description of the instrument employed, since this is the first of the Lick Observatory volumes in which meridian-circle work has appeared. J. E. K.

PRELIMINARY ACCOUNT OF THE RESULTS OBTAINED BY THE CROCKER ECLIPSE EXPEDITION OF THE LICK OBSERVATORY.

Advices received from Professor CAMPBELL, in charge of the Crocker Eclipse Expedition, at Thomaston, Georgia, show that the party had a narrow escape from clouds on the day of the eclipse. The sky was cloudy at sunrise, but it cleared a little later in the morning. Ten minutes before totality large clouds were drifting rapidly toward the Sun, and one minute after third contact the Sun was obscured. Fortunately the sky around the Sun was clear during totality. Mr. CAMPBELL and Mr. PERRINE were aided by fourteen assistants, among whom was Mr. H. D. CURTIS, formerly of the University of the Pacific.

Mr. CAMPBELL reports that the photographs obtained with the 40-foot camera are very fine. The connection between the streamers of the inner corona and the prominences, which was brought out so beautifully on the pictures obtained in India with the same apparatus, is not so apparent on these negatives, but traces of it can probably still be found. The photographs obtained with the smaller cameras are of various degrees of excellence; some are good, and some poor. On the negatives obtained with the Floyd telescope, on slow plates, the streamers of the corona can be traced from three to four solar diameters, or as far as the eye could trace them during the eclipse. The results with the spectroscopic apparatus were less successful. One of the plate-driving clocks, after performing perfectly during every rehearsal, failed at the critical moment. An exposure to the spectrum of the corona was, however, obtained during totality. The observations of contacts were carried out according to the programme.

Notwithstanding the few partial failures recorded above, the success of the party in carrying out its extensive and complicated programme is a source of satisfaction to the Observatory and to all interested in its work. It is also gratifying to record the fact that, so far as known at present, successful observations were secured by all the parties in the line of the eclipse. J. E. K.

ASTRONOMICAL TELEGRAMS.

(Translations.)

To the Lick Observatory, CAMBRIDGE, MASS., April 10, 1900.
Mt. Hamilton. (Received 4 P.M.)

Professor KREUTZ telegraphs as follows:—

"From a discussion of spectrograms, BELOPOLSKY has found the time of rotation of *Venus* to be short. Report sent out by Professor BACKLUND, Director."

(Signed) E. C. PICKERING.

CAMBRIDGE, MASS., April 30, 1900.

To Professor JAMES E. KEELER, (Received 2:25 P.M.)
Lick Observatory.

Arequipa telegraphs that on April 26, 21^h G. M. T., the position of *Eros* was 15′ preceding and 8′ south of the place predicted by JONES's ephemeris.*

(Signed) E. C. PICKERING.

CAMBRIDGE, MASS., May 14, 1900.

To Professor J. E. KEELER: (Received 2:10 P. M.)

Arequipa cables † that the correction to JONES's ephemeris of *Eros* is zero in both Right Ascension and Declination.

(Signed) E. C. PICKERING.

---

* See *Popular Astronomy*, January, 1900, p. 41.

† This message corrects the one received on April 30th. Professor PICKERING writes that the error perhaps arose from assuming that the ephemeris was computed for noon instead of midnight, as the corrections given in the first message are almost exactly half the daily motion of *Eros*.

.GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley California.

A meteor of unusual size and brilliancy fell on the evening of Monday, April 16th, at about 7 P. M., and was seen from Mt. Hamilton as far north as Ashland, Oregon. Unfortunately none of the astronomers at the Lick Observatory witnessed the phenomenon, but one of the ladies who chanced to be standing near a window facing to the north saw it, and described it as a fire-ball many times brighter than *Venus*. It was first seen a little north of the zenith and east of the meridian, and moved slowly northward, disappearing when about 20° from the horizon. Before it disappeared, it separated into two parts, one of which burst a second later with the appearance of a falling rocket. No explosion was heard, and no smoke-cloud was seen.

Newspaper reports show that the meteor was seen throughout the central and northern part of the State. At Chico its course was described as northward and downward. After traversing an arc of 45° it burst, and one large red ball of fire seemed to fly off at an angle from the original course. A small cloud of dense white smoke was visible for nearly half an hour.—*Chico Record.*

The Placer County *Leader* says: "A single ray shot upward at 45° to the west and a ball of fire shot downward at a right angle to it."

At Redding it was seen coming from the high northeastern sky, and passing toward the northwest, leaving a great trail of light and two small clouds of unusual brightness.

From Dunsmuir it was observed to flash out from the northeastern sky and pass toward the southwest. When it exploded, a report like the crack of a rifle was heard. An instant later there was a second explosion, fainter than the first, which completely shattered the meteor. The smoke-clouds were visible for some time afterward.

A letter received at the Lick Observatory from Mr. H. L. WHITED, at Ashland, Oregon, gives the following description:—"It appeared at exactly 7:05 P. M., April 16th, about S. S. E., at an altitude of about 30°, was visible about one second, apparently moving westerly and falling at an angle of 45°. To me it first appeared emerging from a cloud of white smoke with a short trail falling, say 10°, then becoming invisible. We heard no explosion. The cloud of smoke remained in sight till dark, and was in diameter about five or six times as large as the moon."

Three star-catalogues that will be of great value to astronomers generally, and particularly to those engaged in micrometric work, have recently been issued.

The first of these is, in substance, the A. G. Catalogue for the zone + 35° to + 40° Declination, based on observations made at Lund, by N. C. DUNÉR and FOLKE ENGSTRÖM. The catalogue gives the separate observations of each star in the order of Right Ascension for the mean equinox of 1875.0.

The second is the Madras General Catalogue, prepared by C. MICHIE SMITH, the present Director of the Madras and Kodaikanal Observatories, and based on the observations made with the Madras meridian-circle between the years 1862 and 1887, under the direction of the late Government Astronomer, N. R. POGSON. This catalogue gives the positions for 1875.0 of 5,303 stars, including all the brighter stars to the fifth magnitude, inclusive, that could be observed at Madras, and many fainter zodiacal stars and stars south of — 30° Declination.

The third is the Cape Catalogue for 1890.0, based on the meridian observations in the years 1885 to 1895 made at the Cape of Good Hope under the direction of H. M. Astronomer, DAVID GILL.

The working list for this catalogue included, besides several special lists of stars used in the latitude and longitude work of the Geodetic Survey, and as comparison-stars for heliometer work, etc., all the stars of fourth magnitude or brighter which could be conveniently observed from the Cape, and all stars additional to those likely to be required for future use in any of the National Ephemerides, and twenty-four southern circumpolar stars.

In addition to these general catalogues, the annual catalogue of the Greenwich meridian-circle observations for the year 1897 has just been distributed.

In No. 73 of these *Publications*, brief mention was made of a new elementary astronomy by Dr. E. S. HOLDEN, lately published by HENRY HOLT & Co. It may not be inappropriate, however, to give a little further attention to a book from which many young people are likely to receive their first formal notions of the science of astronomy. When called upon to select a text-book for class use the experienced teacher considers the method in which the subject is presented more carefully than the actual facts contained in the book. The latter will be substantially the same for any science in all the better books of about the same date.

We may therefore dismiss the descriptive parts of the book — Parts II and III — with the notice already referred to and the additional statement that while these portions of the work are considerably compressed, the best results of modern research find a place, so far as they are appropriate to an elementary text.

The method in which the author has aimed to present the fundamental concepts of astronomy may be stated most simply by a quotation or two from his Introduction. He says:—

> "The study of astronomy should lead the student to comprehensive ideas of the universe at large. . . . It should be the aim of the text-book and of the teacher to so marshal the most significant of the results of observation that the student may acquire such wide and general views. If he at the same time gains a luminous idea of the most important of the methods by which such results are reached, his teaching has been successful."
>
> "The book is addressed especially to pupils who are studying astronomy for the first time. The chief difficulties of such students are not due to the intrinsic complexity of the separate problems that they meet, but rather to their apparent want of connection one with another, and above all to the unfamiliarity of the student with the methods of reasoning employed. It is therefore necessary to treat each new topic with great clearness, and not to dismiss it until its relation to other topics has been at least partially apprehended. The important point is to present the subject in a way to convince and to enlighten the pupil, and this object can only be attained in a text-book by some repetitions and by avoiding undue brevity."

A careful reading of the 268 pages that constitute the first part of the book will convince any one that Dr. HOLDEN has carried out his method with success, and that any student who has studied the work as it is intended to be studied, thinking out for himself answers to the suggestive questions which accompany each chapter, and making the simple observations as directed, will possess clear notions of the fundamental principles of astronomy.

There is an occasional minor blemish in the way of typographical errors. In general these are of no importance, but some pupils may be misled by the statement of the second law of diurnal motion of the stars (page 49): "The greater the star's north-polar distance, the larger is the [diurnal] circle.'' This, of course, is true for all stars in the northern hemisphere; but from the context the pupil is likely to gather that it is true of the southern stars as well. We also notice that the author seems to prefer the French and English use of the north-polar distance as one of the co-ordinates of a star to the German and American practice of using the declination. But these are points of comparatively little consequence. In all essentials the book is one to be commended to teachers and pupils, as an excellent introduction in matter and method to the study of astronomy.

Telegrams received at the Lick Observatory and the Associated Press dispatches indicate that the total eclipse of the Sun was observed last Monday, May 28th, under unusually favorable conditions. The success of the Lick Observatory Expedition is noted elsewhere in this number. Mr. BURCKHALTER'S programme* was carried out with complete success. His photographs will be looked for with special interest, as they should demonstrate conclusively the effectiveness of his method of controlling the relative lengths of exposure times for different portions of the corona.

A note on Miss O'HALLORAN'S plans for observing the eclipse, both visually and photographically, from a station in Mexico, was accidentally omitted from the April number of these *Publications*.

We are sorry to learn that severe illness prevented Miss O'HALLORAN from carrying out her plans; but in spite of her illness, she viewed the eclipse through a pair of opera-glasses, and sends the following account of her observations:—

NEW ORLEANS, May 28, 1900.

The total eclipse of the Sun was observed here by me in an area of the sky that became entirely free from clouds only about fifteen minutes before second contact. It was then clear and blue. The inner corona became visible to the naked eye nearly one minute before totality, but it seemed shallow and inconspicuous even in the full gloom of eclipse, which resembled early twilight. The outer corona recalled that of January, 1889. The western wing, which extended about one degree from the Moon's limb, widened outwardly. The upper edge pointed almost directly to the planet *Mercury*. The entire outline was sharp and seemed of a streaky structure throughout. The eastern wing was not so distinct except at the base, and it tapered outwardly to invisibility before extending fully a degree. The south polar rays were curved, pointed, and conspicuous. The fleecy white clouds seen half an hour after sunset convey an idea of the general tint of the corona.

---

* See these *Publications* (No. 73, p. 64) for the details of the programme.

Several other members of our Society were observers of this eclipse, among them Mr. COLTON, formerly of the Lick Observatory, who was in charge of the 40-foot photographic telescope of one of the parties sent out by the Naval Observatory.

In a subsequent number we hope to give some account of the scientific results obtained by the various observers.

Dr. WILLIAM LUTHER has been appointed Director of the Observatory at Düsseldorf to succeed his father, the late Robert Luther.

Director JAMES E. KEELER, of the Lick Observatory, has been elected a member of National Academy of Science.

At a recent meeting of the Board of Regents of the University of California, Professor ARMIN O. LEUSCHNER was made head of the Berkeley Astronomical Department. It was formerly a part of the department of Civil Engineering.

Professor GEORGE W. MYERS, Director of the Observatory of the University of Illinois, has resigned his position to take charge of the department of mathematics and astronomy in the Chicago Institute.

Dr. HENRY S. PRITCHETT has resigned his position of Superintendent of the United States Coast and Geodetic Survey to accept the position of President of the Massachusetts Institute of Technology.

PIAZZI SYMTH, a well-known astronomer and spectroscopist, for some time Astronomer Royal of Scotland, died on February 21st. He was born in Naples, and was named after the famous discoverer of *Ceres*.

The meetings of the Board of Directors, and of the Society, on June 9, 1900, were adjourned without the transaction of any business, owing to the lack of a quorum of members.

OFFICERS OF THE SOCIETY.

Mr. James E. Keeler	*President*
Mr. Charles Burckhalter	*First Vice-President*
Miss R. O'Halloran,	*Second Vice-President*
Mr. S. D. Townley	*Third Vice-President*
Mr. C. D. Perrine Mr. F. R. Ziel	*Secretaries*
Mr. F. R. Ziel	*Treasurer*

Board of Directors—Messrs. Burckhalter, Campbell, Dolbeer, Hill, Keeler, Molera, Miss O'Halloran, Messrs. Perrine, Pierson, Townley, Ziel.

Finance Committee—Messrs. Pierson, Burckhalter, Hill.

Committee on Publication—Messrs. Aitken, Townley, von Geldern.

Library Committee—Messrs. Townley, Miss O'Halloran, Miss Hobe.

Committee on the Comet-Medal—Messrs. Keeler (*ex-officio*), Pierson, Burckhalter.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. Ruthven W. Pike.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. Francisco Rodriguez Rey.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

JAMES EDWARD KEELER.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XII. SAN FRANCISCO, CALIFORNIA, OCTOBER 1, 1900. NO. 75.

JAMES EDWARD KEELER.

The Lick Observatory has lost an ideal Director. Astronomy has suffered a loss it can ill afford. Colleagues and friends widespread will miss a companionship which was simply delightful.

JAMES EDWARD KEELER was born in La Salle, Illinois, on September 10, 1857. RALPH KEELER, his first American ancestor, settled in Hartford in 1635. His father, WM. F. KEELER, was an officer of the original *Monitor* at the time of its engagemen with the *Merrimac*. His mother (still living) is the daughter of HENRY DUTTON, former Governor of Connecticut, and Dean of the Yale Law School.

In 1869 the family removed from La Salle, Illinois, to Mayport, Florida. Here KEELER prepared for college under the tutelage of his father and his older brother. Here his fondness for astronomical studies was developed. He established "The Mayport Astronomical Observatory" in 1875–77. It included, at the least, a quadrant, a two-inch telescope, a meridian-circle, and a clock. Under date of 1875, September 22d, his journal records an observed altitude of *Polaris*, secured with "my quadrant." Other entries read:—

"1875, Nov. 14.—Sent to Queen last night for lenses for my telescope."

"1875, Nov. 29.—Lenses from Queen came to-night; one two-inch achromatic, and two plano-convex lenses for eye-piece."

"1875, Dec. 12.—Directed my telescope to the stars, and saw the rings of *Saturn* for the first time. . . ."

"Dec. 14.—Saw the Annular Nebula in *Lyra*. One satellite of *Saturn*. . . . All four of the stars in the Trapeziun. . . ."

"1876, Jan. 26.—Got up at ½ past 4 this morning and applied my telescope to *Jupiter* for the first time. . . ."

In 1877, at the age of twenty years, he constructed a meridian-circle instrument. The telescope of it was that of a common spy-glass, 1.6-inch aperture, and 13.45-inch focus. The axis was turned out of wood. Brass ferrules driven on the ends of the axis, and turned down, formed the pivots. The wooden circle, 13.3 inches in diameter, was graduated to 15′. KEELER'S original sketch of this instrument, and his written description of it, are published elsewhere in this number of the *Publications.*

His "Record of Observations, made at the Mayport Observatory," contains beautiful colored sketches of *Jupiter*, *Saturn*, *Venus*, *Mars*, the *Orion Nebula*, of double stars, and of "Scenery on the Moon"; and in addition, data of a numerical character. These early drawings are characterized by the refined taste and skill so well known from his later professional work.

Mr. KEELER entered Johns Hopkins University late in 1877; and, following major courses in Physics and German, he was graduated with the degree of A. B. in 1881. At the end of his freshman year, he accompanied Professor HASTINGS, as a member of Professor HOLDEN'S party from the Naval Observatory, to observe the total solar eclipse of July 29, 1878, at Central City, Colorado. Although his part was the modest one of making a drawing of the corona, his written report on the work is a model scientific paper, and may be read with profit by visual observers of eclipses.

In the spring of 1881, Professor LANGLEY, desiring an assistant in the Allegheny Observatory, requested the Johns Hopkins University to recommend a suitable man for the place. KEELER was named for and accepted the appointment, beginning work at Allegheny several weeks before receiving his degree. I was speaking, in June of this year (1900) with one of the physicists who had recommended KEELER for the Allegheny position, and the subject of this very appointment came up. "I told Professor LANGLEY," said he, "that one of my strongest reasons for the recommendation is that KEELER does n't claim to know everything." To the end of his life, this charming trait remained unimpaired. It is to KEELER'S credit that he largely defrayed his own expenses in college by acting as assistant to some of the lecturers in the experimental courses.

Professor LANGLEY made his noted expedition to the summit of Mt. Whitney, California, in June–September, 1881, to determine the value of the "Solar Constant." Mr. KEELER accompanied the expedition in the capacity of assistant, and carried out his share of the programme with skill and efficiency. Returning at once to Allegheny, his work until May, 1883, was closely related to the many problems arising from the Mt. Whitney expedition.

The year 1883-4 was devoted to study and travel abroad. The months of June, July, and August, at Heidelberg, were given to the study of Light and Electricity under QUINCKE, Chemistry under BUNSEN, and Integral Calculus under FUCHS. During the winter semester, in Berlin, he heard the lectures on Physics by HELMHOLTZ and KAYSER, on Differential Equations by RUNGE, and on Quaternions by GLAN. His main investigation in the physical laboratory was on "The Absorption of Radiant Heat by Carbon Dioxide," — a problem suggested no doubt by his Mt. Whitney experiences.

From June, 1884 to April, 1886, Mr. KEELER again served as assistant in the Allegheny Observatory, affording most efficient help to Professor LANGLEY in his classical researches on the lunar heat, and on the infra-red portion of the solar spectrum.

Early in 1886, on Professor HOLDEN'S recommendation, Mr. KEELER was appointed Assistant to the Lick Trustees. He arrived at Mt. Hamilton on April 25, 1886, and immediately proceeded to establish the time service. The telegraph line to San José was perfected, the transit instruments, the clocks, and the sending and receiving apparatus at both ends of the line, were installed. The signals were sent out on and after January 1, 1887; north to Portland, east to Ogden, and south to San Diego and El Paso. In addition to the time service, he assisted the Trustees in installing the various instruments.

When the Observatory was completed, and transferred to the Regents of the University of California, on June 1, 1888, Mr. KEELER was appointed Astronomer; the original staff consisting of Astronomers HOLDEN, BURNHAM, SCHAEBERLE, KEELER and BARNARD, and Assistant Astronomer HILL.

Professor KEELER was placed in charge of the spectroscopic work of the Observatory. The large star spectroscope, constructed mainly from his designs, has no superior for visual observations. Of the many results obtained with this instrument we may mention the observations of *Saturn's* rings and *Uranus*, with reference to their atmospheres; of the bright and dark lines in the spectra of γ *Cassiopeiæ* and β *Lyræ;* of the color curve of the 36-inch equatorial; and of the spectra of the *Orion Nebula* and thirteen planetary nebulæ.

His beautiful observations on the velocities in the line of sight of these fourteen nebulæ mark a distinct epoch in visual spectroscopy. His memoir on the subject took its place as a classic at once. The probable error of the final result for each nebula, based on the mean of several observations, is only ± 3.2 kilometers per second. Attention should be called to one extremely important fact established by these measures, viz: the velocities of the nebulæ in their motion through space are of the same order of magnitude as the velocities of the stars.

The recognition of the fact that a great refracting telescope is also a most powerful spectroscope for special classes of objects, by virtue of the chromatic aberration of the objective, is due to Professor KEELER. Among the first objects observed with the 36-inch equatorial were the planetary nebulæ and their stellar nuclei. The observers were struck with the fact that the focal length for a nebula is 0.4 inch longer than for its stellar nucleus; a discrepancy which Professor KEELER at once explained by recalling that the star's light is yellow, whereas that of the nebula is greenish-blue.

Astronomical readers will remember KEELER'S splendid drawings of the planets *Saturn*, *Jupiter*, and *Mars*, made with the assistance of the 36-inch telescope, during 1888–90. His faithful and artistic drawings of *Jupiter* have no equal.

He was in charge of the very successful expedition sent by the Lick Observatory to Bartlett Springs, California, to observe the solar eclipse of January 1, 1889.

Professor KEELER resigned from the Lick Observatory staff on June 1, 1891, to succeed Professor LANGLEY as Director of the Allegheny Observatory and Professor of Astrophysics in the Western University of Pennsylvania. The Allegheny Observatory has perhaps the poorest location of any observatory in this country for spectroscopic work. But in spite of this disadvantage, KEELER'S investigations continued and promoted the splendid reputation established for the observatory by his predecessor. He comprehended the possibilities and limitations of his situation and his means, and adapted himself to them. His spectroscopic researches were largely confined to the orange, yellow, and green regions of the spectrum, since these would be less strongly affected by the smoky sky, for which that vicinity is famous.

The Allegheny spectroscope, designed and constructed soon after his acceptance of the position, contained several valuable improvements. The use of three simple prisms in its dispersive train was a departure which has been followed with great advantage in many later instruments. With this instrument he made an extensive investigation of the *Orion Nebula* and the stars immersed in it, establishing the fact that the nebula and the stars are closely related in physical condition.* His beautiful observations of *Saturn's* rings, proving that they are a cluster of meteorites — myriads of little moons — have never been surpassed in interest in the entire astronomical field. These observations are so well known to every one interested in astronomy that a single sentence suffices. He proved spectrographically, using the Doppler-Fizeau principle, that every point in the ring system is moving with the velocity which a moon would have if situated at that distance from the planet. Professor KEELER'S main piece of work at the Allegheny Observatory, on the spectra of the third (Secchi) type stars remains unpublished, but the measures and reductions are left in an advanced stage.

The Regents of the University of California appointed Professor KEELER to the position of Director of the Lick Observatory on March 8, 1898. The ties which bound him and his family to Allegheny were difficult to sever; but the greater opportunities offered by the instruments and the atmospheric conditions at Mt. Hamilton decided him in favor of accepting the appointment. He entered upon his new duties on June 1, 1898.

Without making any rearrangement of the work of the staff, but affording them every possible encouragement to continue along the same lines, Professor KEELER arranged to devote his own observing-time to the Crossley reflector. He recognized that the instrument was not in condition to produce satisfactory results. He made one change after another, overcoming one difficulty after another, until, on November 14th, he secured an excellent negative of the *Pleiades*, and on November 16th, a superb negative of the *Orion Nebula*. The enormous power of the reflector in nebular photography was established, and he entered upon the programme of photographing all the brighter nebulæ in HERSCHEL'S catalogue. More than half of the subjects on the programme have been completed. The Observatory possesses a set of negatives of the principal nebulæ which is priceless and unequaled. These photographs have already led to many discoveries of prime importance; and they furnish a vast amount of material for future investigations of questions bearing especially upon the early stages of sidereal evolution. The photographs record, incidentally, great numbers of new nebulæ; as many as thirty-one on a single plate covering less than one square degree of the sky. A conservative estimate places the number within reach of the Crossley reflector at 120,000, of which only ten or fifteen thousand have thus far been discovered.

---

*Simultaneous observations of the same object made at another observatory led to the same conclusion.

It has previously been supposed that the great majority of nebulæ are irregular and without form, and that only a few are spirals. Professor KEELER'S photographs have recorded more spiral nebulæ than irregular ones. This discovery bears profoundly on the theories of the cosmogony, and must be considered as of the first order.

It is time to refer to Professor KEELER'S work as Director. I but faintly reflect the views of every member of the staff, and indeed of all who have been interested in the work of this Observatory, when I say that his administration was completely successful. He cherished and promoted ideal conditions in this ideal place. He made a success of his own work, in a splendidly scientific manner; and he saw to it that every one had all possible opportunities to do the same. No member of the staff was asked to sacrifice his individuality in the slightest degree. Nor were demands made for immediate results. No one's plans were torn up by the roots to see if they were growing. The peace of mind of the investigator, so absolutely essential for complete success, was full and undisturbed. Withal, Professor KEELER'S administration was so kind and so gentle, and yet so effective, that the reins of government were seldom seen and never felt.

The elements of his successes are simple, and plainly in view. His openness and honesty of character, his readiness and quickness to see the other man's point of view, his strong appreciation of the humorous, as well as the serious, and above all his abounding good sense,— these traits made his companionship delightful and charming. Scientifically, Professor KEELER never groped aimlessly in the dark. He would not attack a problem until he had as fully as possible comprehended its nature, and the requirements for success. With the plan of attack completely considered, and the instruments of attack at hand, the execution of his plans involved little loss of time. The Crossley reflector affords a case in point. Assisted by a Fellow in Astronomy and by the instrument-maker, he devoted five months to preparing the reflector for turning out the magnificent results which *at once* followed.

Professor KEELER's published papers have a finish and a ripeness which are rarely seen. His love of the beautiful and his artistic skill are evident in all his work.

To speak of the people who had afforded him encouragement at different times in his life, was one of his pleasures. His father's friend, Mr. CHAS. H. ROCKWELL, of Tarrytown, was constant in urging the development of so promising a career. He did not forget Professor HASTINGS' continual kindness and interest during his college days. He frequently spoke of the great value of Mr. WILLIAM THAW's interest and encouragement, both to himself and to the Allegheny Observatory; an interest which was continued after Mr. THAW's death by other members of Mr. THAW's family.

The honorary degree of Sc. D. was conferred upon Professor KEELER in 1893 by the University of California. He received the Rumford medal from the American Academy of Arts and Sciences in 1898, and the Henry Draper medal from the National Academy of Sciences in 1899. He was a member of the National Academy of Sciences; an Associate of the American Academy of Arts and Sciences; a Fellow and Foreign Associate of the Royal Astronomical Society; a Fellow of the American Association for the Advancement of Science; a member and officer of the Astronomical and Astrophysical Society of America; an honorary member of the Toronto Astronomical and Physical Society; the President of the Astronomical Society of the Pacific; a member of the Washington Academy of Sciences, and various other organizations.

It appears that Professor KEELER had long been a sufferer from a mild form of heart weakness; to run even fifteen steps caused him great physical distress. It is feared that on Mt. Hamilton he worked beyond his strength. His weakness seemed to develop rapidly this summer. He went away from the Observatory on July 30th, in the best of spirits, and with no anxiety, to secure medical treatment, and to spend a brief vacation in the northern part of the State. Increasing difficulty in breathing led him to seek skilled treatment in San Francisco, on August 10th.

His dangerous condition was recognized on August 11th, and on the 12th a stroke of apoplexy proved fatal.

When the dangerous weakness of his heart was discovered by the physicians, Professor KEELER'S main regret was that he would have to leave Mt. Hamilton and its opportunities, in order to live at a lower altitude. It is known that he had planned his work with the Crossley reflector far into the future. A small spectrograph which he was most anxious to employ on certain interesting spectra was completed on the day of his leaving the Observatory.

The absence of one so old in experience and so ripe in judgment will be seriously felt throughout his profession.

Professor KEELER married Miss CORA S. MATTHEWS at Oakley Plantation, Louisiana, on June 16, 1891. Of her great sorrow, and of the grievous loss to the two children, it would be futile to speak.

W. W. CAMPBELL.

THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY.*

By JAMES E. KEELER.

The Crossley reflector, at present the largest instrument of its class in America, was made in 1879 by Dr. A. A. COMMON, of London, in order to carry out, and test by practical observation, certain ideas of his respecting the design of large reflecting telescopes. For the construction of the instrument embodying these ideas, and for some fine astronomical photographs obtained with it, Dr. COMMON was awarded the gold medal of the Royal Astronomical Society in 1884.

In 1885, Dr. COMMON, wishing to make a larger telescope on a somewhat similar plan, sold the instrument to EDWARD CROSSLEY, Esq., F. R. A. S., of Halifax, England. Mr. CROSSLEY provided the telescope with a dome of the usual form, in place of the sliding roof used by its former owner, and made observations with it for some years; but the climate of Halifax not being suitable for the best use of such a telescope, he consented, at the request of Dr. HOLDEN, then Director of the Lick Observatory, to present it to this institution. The funds for transporting the telescope and dome to California, and setting them up on Mt. Hamilton, were subscribed by friends of the Lick Observatory, for the most part citizens of California. The work was completed, and the telescope housed in a suitable observatory building, in 1895.*

---

* Reprinted from the *Astrophysical Journal* for June, 1900.

On taking charge of the Lick Observatory in 1898, I decided to devote my own observing time to the Crossley reflector, although the whole of my previous experience had been with refracting telescopes. I was more particularly desirous of testing the reflector with my own hands, because such preliminary trials of it as had been made had given rise to somewhat conflicting opinions as to its merits.† The result of my experience is given in the following article, which is written chiefly with reference to American readers. If I have taken occasion to point out what I regard as defects in the design or construction of the instrument, I have done so, not from any desire to look a gift horse in the mouth, but in the interest of future improvement, and to make intelligible the circumstances under which the work of the reflector is now being done and will be done hereafter. The most important improvements which have suggested themselves have indeed already been made by Dr. COMMON himself, in constructing his five-foot telescope. The three-foot reflector is, in spite of numerous idiosyncrasies which make its management very different from the comparatively simple manipulation of a refractor, by far the most effective instrument in the Observatory for certain classes of astronomical work. Certainly no one has more reason than I to appreciate the great value of Mr. CROSSLEY's generous gift.

The Crossley dome is about 350 yards from the main Observatory, at the end of a long rocky spur which extends from the Observatory summit toward the south, and on which are two of the houses occupied by members of the Observatory staff. It is below the level of the lowest reservoir, "Huyghens," which receives the discharge from the hydraulic machinery of the 36-inch refractor, and therefore the water-engine furnished by Mr. CROSSLEY for turning the dome cannot be used, unless a new water system — overflow reservoir, pump and windmill — is provided. In this respect a better site would have been a point on the south slope of "Kepler,"— the middle peak of Mt. Hamilton —just above the Huyghens reservoir. No addition to the present water system would then have been needed. The slope of the mountain at this place might cut off the view of the north horizon, but since the telescope cannot be turned below the pole, this would be a matter of no consequence. Water-power for the dome is not, however, really necessary.

---

* For a more complete history of this part of the subject, see Dr. Holden's articles in *Pub. Ast. Soc. Pacific*, No. 7, 197 *et seq.*, 1895.

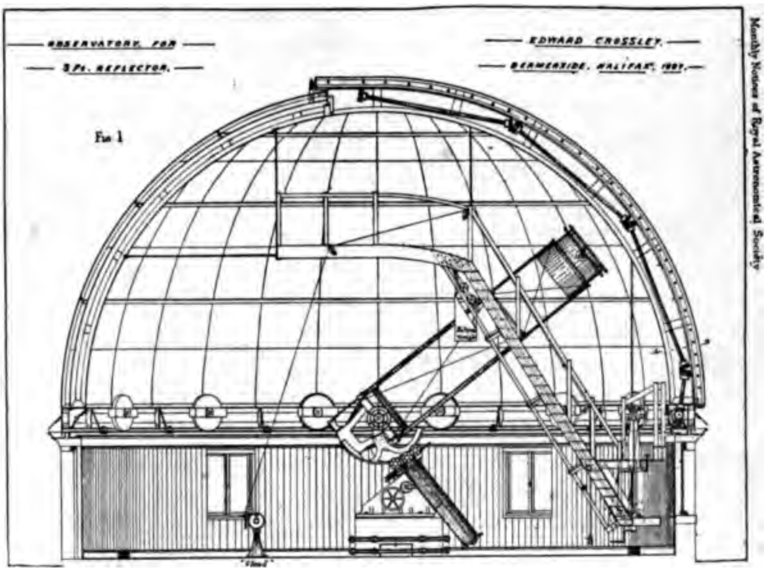
† The difficulties here referred to, about which a good deal has been written, seem to have had their origin in the fact that it was impossible, at the time of the preliminary trials, to provide the observer with an assistant, while the Crossley reflector is practically unmanageable by a single person.

The cylindrical walls of the dome, 36¼ feet inside diameter, are double, and provided with ventilators. Opening into the dome, on the left of the entrance, are three small rooms, one of which has been fitted up as a photographic dark room, and another, containing a sidereal clock and a telephone which communicates with the main Observatory, as a study, while the third is used for tools and storage. There is also a small room for the water-engine, in case it should be used. The dome is at present supplied with water from only the middle reservoir, Kepler, which is reserved for domestic purposes and is not allowed to pass through the machinery.

The dome itself, 38 feet 9 inches in diameter, is made of sheet-iron plates riveted to iron girders. It also carries the wooden gallery, ladders, and observing platform, which are suspended from it by iron rods. The apparatus for turning the dome consists of a cast-iron circular rack bolted to the lower side of the sole-plate, and a set of gears terminating in a sprocket-wheel, from which hangs an endless rope. As the dome does not turn easily, it has been necessary to multiply the gearing of the mechanism so that one arm's-length pull on the rope moves the dome only about one inch. In some positions of the telescope the dome cannot be moved more than six or eight inches at a time without danger of striking the tube, and this slowness of motion is then not disadvantageous. It is only when the dome has to be moved through a considerable angle, as in turning to a fresh object, or in photographing some object which passes nearly through the zenith, that the need for a mechanical means of rotation is felt.

The observing slit, 6 feet wide, extends considerably beyond

the zenith. It is closed by a double shutter, which is operated by an endless rope. The upper part, within the dome, is also closed by a hood, or shield, which serves to protect the telescope from any water that may find its way through the shutter, and which is rolled back to the north when observations are made near the zenith. I have recently fitted the lower half of the slit with a wind-screen, which has proved to be a most useful addition. It is made of tarpaulin, attached to slats which slide between the two main girders, and is raised or lowered by halyards, which belay to cleats on the north rail of the gallery. A more detailed description of the dome has been given in an article by Mr. CROSSLEY,* from which the reduced figure in Fig. I† has been taken.



Monthly Notices of Royal Astronomical Society

THE CROSSLEY REFLECTOR.

The mounting of the three-foot reflector has been very completely described and illustrated by Dr. COMMON,‡ so that only a very general description need be given here. The most important feature of the mounting is that the telescope-tube, instead of being on one side of the polar axis, as in the usual construction, is central, so that the axis of the mirror and the polar axis are in the same line when the telescope is directed to the pole. The declination axis is short, and is supported by a massive goose-neck bolted to the upper end of the polar axis. The mirror is placed just *above* the declination axis. Its weight, and the weight of the whole tube and eye-end, are counterpoised by slabs of lead, placed in two iron boxes, between which the goose-neck of the polar axis passes. The great advantage of this arrangement, and the controlling principle of the design, is that the telescope is perfectly free to pass the meridian at all zenith distances. No reversal of the instrument is needed, or is indeed possible.

---

* *Mon. Not. R. A. S.*, No. 48, 386.

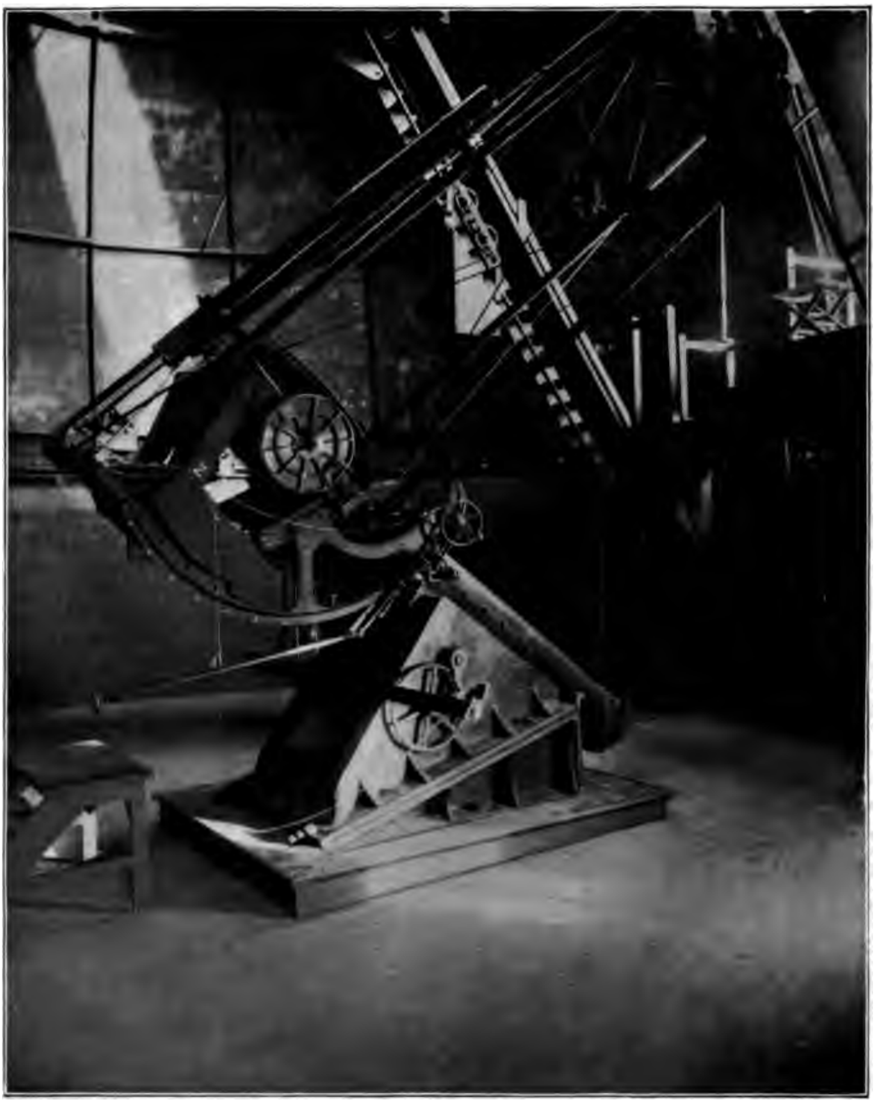
† Kindly lent by the Astronomical Society of the Pacific.

‡ *Mem. R. A. S.*, No. 46, 173.

For long-exposure photography, the advantage above referred to is obvious, but it is attended by certain disadvantages. One of these is that a very much larger dome is required than for the usual form of mounting. Another is the great amount of dead weight which the axis must carry; for the mirror, instead of helping to counterpoise the upper end of the tube, must itself be counterpoised. When anything is attached to the eye-end (and in astrophysical work one is always attaching things to the eye-end of a telescope), from ten to twenty times as much weight must be placed in the counterpoise boxes below the declination axis. Where room is to be found for the weights required to counterpoise the Bruce spectrograph, is a problem which I have not yet succeeded in solving.

In his five-foot reflector, Dr. COMMON has caused the telescope tube to swing between two large ears, which project from the upper end of the boiler-like polar axis, the pivots constituting the declination axis being near, but above, the lower end of the tube. The mirror therefore helps to counterpoise the upper end of the tube. This I regard as a distinct improvement. The danger of large masses of metal near the mirror injuring the definition is, in my opinion, imaginary; at least there is no such danger on Mt. Hamilton, where the temperature variations are unusually small. Experience with the Crossley reflector, as well as with the other instruments of the Lick Observatory, shows that the definition depends almost entirely on external conditions.

My first trials of the reflector, as first mounted at the Lick Observatory, showed that the center of motion was inconveniently high. Among other difficulties arising from this circumstance, the spectroscope projected beyond the top of the dome, so that it had to be removed before the shutter could be closed. In July,



THE CROSSLEY REFLECTOR.

1898, the pier was therefore cut down two feet. This brought the eye-end down nearly to the level of the gallery rail, where it was at a convenient height for the observer when sitting on a camp-stool, and it made all parts of the mounting more accessible. Toward the north and south, the range of the telescope, being limited in these directions by the construction of the mounting, was not affected by the change, but the telescope cannot now be used at such low altitudes as formerly, near the east and west points of the horizon. The only occasion likely to call for the use of the reflector in these positions is the appearance of a large comet near the Sun, and after some consideration, I decided to sacrifice these chances for the sake of increasing the general usefulness of the instrument. Except in rare cases, all observations are made within three hours of the meridian.

To adapt the mounting to the latitude of Mt. Hamilton, a wedge-shaped casting, shown in the accompanying plate, had been provided, but through some error, arising probably from the fact that the telescope had been used in two different latitudes in England, the angle of the casting was too great. When the pier was cut down, its upper surface was therefore sloped toward the south in order to compensate the error in the casting. The plate shows the instrument very nearly as it is at the present time.

The polar axis of the Crossley reflector is a long, hollow cylinder, separated by a space of about one eighth of an inch from its concentric casing. The idea was to fill this space with mercury, and float the greater part of the thrust of the axis, the function of a small steel pin at the lower end being merely to steady the axis. But this mercury flotation, as applied to the Crossley telescope, is a delusion, as I think Mr. CROSSLEY had already found. The mercury, it is true, relieves the thrust to some extent, but it greatly increases the already enormous side pressure on the steel pin at the bottom, thus creating a much greater evil than the one it is intended to remedy. The workmen who set up the mounting inform me that the small bearing at the lower end of the polar axis is badly worn, as I should expect it to be. Instead of putting mercury into the space intended for it, I have therefore poured in a pint or so of oil, to keep the lower bearing lubricated. For the reasons indicated above, the force required to move the telescope in right ascension is perhaps five times greater than it should be. The lower end of the polar axis ought to be fitted with ball bearings to take the thrust, and with a pair of friction wheels on top; but it would be difficult to make these changes now. It should be observed that the disadvantages of the mercury flotation are considerably greater at Mt. Hamilton than at the latitude for which the telescope was designed.

As already stated above, the range of the telescope is limited on the south by the construction of the mounting. The greatest southern declination which can be observed is 25°. In England this would doubtless mark the limit set by atmospheric conditions, but at Mt. Hamilton it would be easy to photograph objects 15° farther south, if the telescope could be pointed to them.

The original driving-clock having proved to be inefficient, at least without an electric control, a new and powerful driving-clock was made by the Observatory instrument-maker, from designs by Professor HUSSEY. In its general plan it is like that of the 36-inch refractor. The winding apparatus contained in the large casting of the original mounting has no maintaining power, and cannot easily be fitted with one. The clock could in no case be wound during a photographic exposure, on account of the tremors attending the operation, but it would be somewhat more convenient to have the stars remain on the plate during the winding. With a little practice, however, one can wind the clock without actually stopping it, though the object must afterwards be brought back to its place by means of the slow motion in right ascension.

Two finders have recently been fitted to the Crossley reflector. One has an object-glass of four inches aperture and eight feet six inches focal length, with a field of about 1° 2′, which is very nearly the photographic field of the main telescope. Its standards are bolted to one of the corner tubes of the reflector, as shown in the plate (page 151). The other finder has a three-inch objective and a large field. It had not been mounted when the photograph for the plate was made.

When a telescope is used for photographing objects near the pole, with long exposures, the polar axis must be quite accurately adjusted, for otherwise the centers of motion of the stars and of the telescope will not agree, and the star images will be distorted. It is true that with a double-slide plate-holder, like the one used with the Crossley reflector, one star — namely the guiding star — is forced to remain in a fixed position with respect to the plate;

but the differential motion of the other stars causes them to describe short arcs, or trails, around this star as a center. A considerable part of the spring of 1899 was spent in efforts to perfect the adjustment of the polar axis, an operation which, on account of the peculiar form of the mounting, offers unusual difficulties.

In the first plan which was tried, the reflector was used as a transit instrument. The inclination of the declination axis was determined with a hanging level which had been provided by Mr. CROSSLEY, the hour circle and polar axis being very firmly clamped. The clock correction being known from the records kept at the Observatory, the collimation and azimuth constants were found by the usual formulæ. This method failed to give satisfactory results, and it was found later that the declination and polar axis were not exactly at right angles.

There is only one part of the sky on which the telescope can be reversed; namely, the pole. A method which promised well, and on which some time was spent, consists in photographing the pole (the declination axis being horizontal) by allowing the stars near it to trail for ten or fifteen minutes, then turning the polar axis 180° and photographing the pole again on the same plate. Half the distance between the images gives the error of the polar axis, which, if the plate is properly oriented, is easily resolved into horizontal and vertical components; while the distance of each image from the center of the plate is this error increased or diminished by twice the deviation of the telescope axis. In this case the vertical component depends upon the reading of the declination circle, and the horizontal component gives the error of collimation. This method failed, however, to give consistent results, mainly on account of instability of the mirror, and was abandoned.

The use of the large mirror for purposes of adjustment was finally given up, and the axis was adjusted by observations of *Polaris* with the long finder, in the usual manner. In order to reach the star at lower culmination the finder tube had to be thrown out of parallelism with the main telescope.

The base-plate having no definite center of rotation in azimuth, and the wedges and crowbars used for moving it being uncertain in their action, a watch telescope, provided with a micrometer eye-piece, was firmly secured to the mounting throughout these operations, in such manner that a mark on the southern horizon could be observed through one of the windows of the dome. The errors of the polar axis were finally reduced to within the limits of error of observation.

The movable hour-circle and driving-wheel of the Crossley reflector has two sets of graduations. The driving-screw having been thrown out of gear, the circle is turned until the outer vernier indicates the sidereal time, whereupon the driving-screw is thrown into gear again. The inner vernier is then set to the right ascension of the object which it is desired to observe. As an inconsistency of minor importance in the design of the mounting, I may note that the slow motion in right ascension changes the reading of the outer vernier instead of that of the inner one. In practice, however, no inconvenience is caused by this construction.

In the early experiments and photographic work with the Crossley telescope, irregularities in driving were a source of great annoyance. Dr. ROBERTS, in laying down the conditions which should be fulfilled by a good photographic telescope, says that a star should remain bisected by a thread in the eye-piece for two minutes at a time. The Crossley telescope was so far from fulfilling this condition that a star would not keep its place for two consecutive seconds; and the greatest alertness on the part of the observer did not suffice to insure round star-images on a photographic plate. It was obvious that the fault did not lie with the driving-clock; in fact, many of the sudden jumps in right ascension, if explained in this way, would have required the clock to run backward; nevertheless the clock was tested by causing its revolutions to be recorded on a chronograph at the main Observatory, together with the beats of one of the standard clocks. For this purpose a break-circuit attachment was made by Mr. PALMER. The errors of the clock were in this way found to be quite small.

The principal source of the irregularities was found in the concealed upper differential wheel of the Grubb slow motion. This wheel turned with uncertain friction, sometimes rotating on its axis, and sometimes remaining at rest. After it was checked the driving was much better, and was still further improved by repairing some defective parts of the train. Small irregularities still remain. They seem to be partly due to inaccuracies in the cutting of the gears, or of the teeth of the large driving-wheel, and partly to the springing of the various parts, due to the very considerable friction of the polar axis in its bearings. The remaining irregularities are so small, however, that they are easily corrected by the screws of the sliding plate-holder, and with reasonable attention on the part of the observer, round star-images are obtained with exposures of four hours' duration.

The large mirror, the most important part of the telescope, has an aperture of three feet, and a focal length of 17 feet 6.1 inches. It was made by Mr. CALVER. Its figure is excellent. On cutting off the cone of rays from a star, by a knife-edge at the focus, according to the method of FOUCAULT, the illumination of the mirror is very uniform, while the star-disks as seen in an ordinary eye-piece are small and almost perfectly round. They are not, I think, quite so good as the images seen with a large refractor; still, they are very good, indeed, as the following observations of double stars, made recently for this purpose, will show.

Several close double stars were examined on the night of April 17, 1900, with a power of 620. The seeing was four on a scale of five. The magnitudes and distances of the components, as given in the table, are from recent observations by Professor HUSSEY with the 36-inch refractor.

Star	Mag.	*d.*	Result of Obs.
OΣ 208 (*φ Urs. Maj.*)	5.0, 5.5	0″.35	Not resolved; too bright.
OΣ 249, AB	7.2, 8.0	0 .54	Easily resolved.
OΣ 250	7.7, 8.0	0 .44	Resolved.
OΣ 267	8.0, 8.2	0 .30	Just resolved at best moments.

Although the theoretical limit of resolution for a three-foot aperture is not reached in these observations, I do not think the mirror can do any better.

The small mirror, or flat, at the upper end of the tube, is circular, the diameter being nine inches. Its projection on the plane of the photographic plate is therefore elliptical; but the projection of the mirror and its cell on the plane of the great mirror is very nearly circular.

The small mirror, acting as a central stop, has the effect of diminishing the size of the central disk of the diffraction pattern, at the expense of an increase in the brightness of the system of rings. To this effect may be due, in part, the inferiority of the reflector for resolving bright doubles, as compared with a refractor of the same aperture. For photographic purposes, it is evident that the mirror is practically perfect.

The upper end of the tube can be rotated, carrying with it the flat and the eye-end. Whenever the position is changed, the mirrors have to be re-collimated. In practice it is seldom necessary to touch the adjusting screws of the mirrors themselves. The adjustment is effected by means of clamping and butting screws on the eye-end, and a change of the line of collimation with respect to the finders and the circles is avoided. The operation is generally referred to, however, as an adjustment of the mirrors.

For adjusting the mirrors there are two collimators. One of these is of the form devised by Mr. CROSSLEY.* It is very convenient in use, and is sufficiently accurate for the adjustment of the eye-end when the telescope is used for photographic purposes, inasmuch as the exact place where the axis of the large mirror cuts the photographic plate is not then a matter of great importance, so long as it is near the center. Moreover, as stated farther below, the direction of the axis changes during a long exposure. The other collimator is of a form originally due, I think, to Dr. JOHNSTONE STONEY. It consists of a small telescope, which fits the draw-tube at the eye-end. In the focus of the eye-piece are, instead of cross-wires, two adjustable terminals, between which an electric spark can be passed, generated by a small induction machine, like a replenisher, held in the observer's hand. The terminals are at such a distance inside the principal focus of the objective, that the light from the spark, after reflection from the flat, appears to proceed from the center of curvature of the large mirror. The rays are therefore reflected back normally, and form an image of the spark which, when the mirrors are in perfect adjustment, coincides with the spark itself. The precision of this method is very great. It is in fact out of proportion to the degree of refinement attained in other adjustments of the reflector, for a slight pressure of the hand on the draw-tube, or movement of the telescope to a different altitude, instantly destroys the perfection of the adjustment. I have provided these collimators with an adapter which fits the photographic apparatus, so that one can adjust the mirrors without having to remove this apparatus and substitute for it the ordinary eye-end carrying the eye-pieces.

For visual observation the Crossley telescope is provided with seven eye-pieces, with powers ranging from 620 downward.

---

* *Mon. Not. R. A. S.*, No. 48, 280, 1888

The lowest power is only 60, and consequently utilizes only twelve inches of the mirror, nine of which are covered by the central flat. It is therefore of little value, except for finding purposes. The next lowest power utilizes twenty-eight inches of the mirror. The other eye-pieces call for no remark.

But, while the Crossley reflector would doubtless be serviceable for various kinds of visual observations, its photographic applications are regarded as having the most importance, and have been chiefly considered in deciding upon the different changes and improvements which have been made.

The interior of the dome is lighted at night by a large lamp, which is inclosed in a suitable box or lantern, fitted with panes of red glass, and mounted on a portable stand. In order to diffuse the light in the lower part of the dome, where most of the assistant's work is done, the walls are painted bright red; while to prevent reflected light from reaching the photographic plate, the inner surface of the dome itself, the mounting, and the ladders and gallery are painted dead black. The observer is therefore in comparative darkness, and not the slightest fogging of the plate, from the red light below, is produced during a four-hours' exposure. On the few occasions when orthochromatic plates are used, the lamp need not be lighted.

Experiments have shown that the fogging of the photographic plate, during a long exposure, is entirely due to diffuse light from the sky, and is therefore unavoidable. For this reason the cloth curtains which lace to the corners of the telescope-tube, inclosing it and shutting out light from the lower part of the dome, have not been used, since their only effect would be to catch the wind and cause vibrations of the telescope. They would probably have little effect on the definition, and at any rate could not be expected to improve it.

For photographing stars and nebulæ the Crossley reflector is provided with a double-slide plate-holder, of the form invented by Dr. COMMON.* This apparatus, which had suffered considerably in transportation, and from general wear and tear, was thoroughly overhauled by the Observatory instrument-maker. The plates were straightened and the slides refitted. A spring was introduced to oppose the right-ascension screw and take up the lost motion — the most annoying defect that such a piece of apparatus can have — and various other improvements were made, as the necessity for them became apparent. They are described in detail farther below.

---

* *Mon. Not. R. A. S.*, No. 49, 297. The construction here described is not followed exactly in the Crossley apparatus. The guiding eye-piece slides freely when not held by a clamp. Pin-holes for preventing fogging are unnecessary when red light is used.

The present appearance of the eye-end is shown in the plate facing p. 159. The plate-holder is there shown, however, on one side of the tube, and its longer side is parallel to the axis of the telescope. This is not a good position for the eye-end, except for short exposures. In practice, the eye-end is always placed on the north or south side of the tube, according as the object photographed is north or south of the zenith. The right-ascension slide is then always at right angles to the telescope axis, and the eye-end cannot get into an inaccessible position during a long exposure.

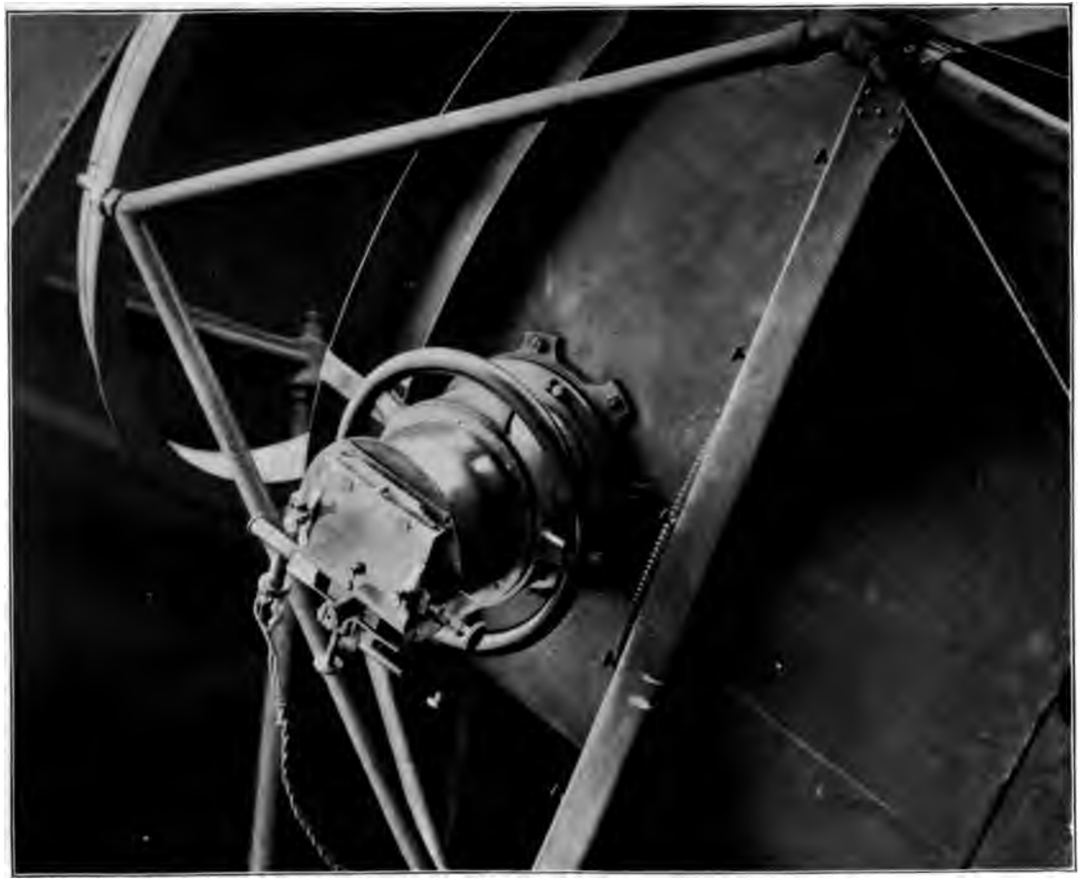
As the original wooden plate-holders were warped, and could not be depended upon to remain in the same position for several hours at a time, they were replaced by new ones of metal, and clamping-screws were added, to hold them firmly in place. The heads of these screws are shown in the plate, between the springs which press the plate-holder against its bed.

To illuminate the cross-wires of the guiding eye-piece, a small electric lamp is used, the current for which is brought down from the storage battery at the main Observatory. The coarse wires have been replaced by spider's webs,* and reflectors have been introduced, to illuminate the declination thread. A collimating lens, placed at its principal focal distance from the incandescent filament of the lamp, makes the illumination of the wires nearly independent of their position on the slide, and a piece of red glass, close to the lens, effectually removes all danger of fogging the plate. The light is varied to suit the requirements of observation by rotating the reflector which throws the light in the direction of the eye-piece.

In long exposures it is important for the observer to know at any moment the position of the plate with reference to its central or zero position. For this purpose scales with indexes are attached to both slides; but as they cannot be seen in the dark, and, even if illuminated with red light, could not be read without removing the eye from the guiding eye-piece, I have added two

---

* It so happens that the tension of the vertical thread is such that it begins to slacken when the temperature falls to within about 2° of the dew point. The thread thus forms an excellent hygrometer, which is constantly under the eye of the observer. When the thread becomes slack, it is time to cover the mirrors.



DOUBLE-SLIDE PLATE-HOLDER OF THE CROSSLEY REFLECTOR.

short pins, one of which is attached to the lower side of the right-ascension slide, and the other to its guide, so that the points coincide when the scale reads zero. These pins can be felt by the fingers, and with a little practice the observer can tell very closely how far the plate is from its central position. It would not be a very difficult matter to improve on this contrivance, say by placing an illuminated scale, capable of independent adjustment, in the field of the eye-piece, but the pins answer every purpose. The declination slide is changed so little that no means for indicating its position are necessary.

In this apparatus, as originally constructed, the cross-wires of the guiding eye-piece were exactly in the plane of the photographic plate. The earlier observations made with the Crossley reflector on Mt. Hamilton showed that this is not the best position of the cross-wires. The image of a star in the guiding eye-piece, which, when in the middle of its slide, is nearly three inches from the axis of the mirror, is not round, and its shape varies as the eye-piece is pushed in or drawn out. In the plane of the photographic plate (assumed to be accurately in focus), it is a crescent, with the convex side directed toward the center of the plate. This form of image is not suitable for accurate guiding. Outside this position the image changes to an arrow-head, the point of which is directed toward the axis, and this image can be very accurately bisected by the right-ascension thread. As the construction of the apparatus did not allow the plane of the cross-wires to be changed, the wooden bed of the plate-holder was cut down, so as to bring the wires and the plate into the proper relative positions.

After some further experience with the instrument, still another change was made in this adjustment. It was found that the focus often changed very perceptibly during a long exposure, and while the arrow-head image above described was suitable for guiding purposes, its form was not greatly affected by changes of focus. Between the crescent and the arrow-head images there is a transition form, in which two well-defined caustic curves in the aberration pattern intersect at an acute angle. The intersection of these caustics offers an excellent mark for the cross-wires, and is at the same time very sensitive to changes of focus, which cause it to travel up or down in the general pattern. The bed of the plate-holder was therefore raised, by facing it with a brass plate of the proper thickness.

Why the focus of the telescope should change during a long exposure is not quite clear. The change is much too great to be accounted for by expansion and contraction of the rods forming the tube, following the changes of temperature, while a simple geometrical construction shows that a drooping of the upper end of the tube, increasing the distance of the plate from the (unreflected) axis of the mirror, cannot displace the focus in a direction normal to the plate, if it is assumed that the field is flat. The observed effect is probably due to the fact that the focal surface is not flat, but curved. During a long exposure, the observer keeps the guiding-star, and therefore, very approximately, all other stars, in the same positions relatively to the plate; but he has no control over the position of the axis of the mirror, which, by changes of flexure, wanders irregularly over the field. The position of maximum curvature, therefore, also varies, and with it the focus of the guiding-star relatively to the cross-wires, where the focal surface is considerably inclined to the field of view. It is certain that the focus does change considerably, whatever the cause may be, and that the best photographic star-images are obtained by keeping the focus of the guiding-star unchanged during the exposures. This is done by turning the focusing-screw of the eye-end.

In making the photographs of nebulæ for which the Crossley telescope is at present regularly employed, it was at first our practice to adjust the driving-clock as accurately as possible to a sidereal rate, and then, when the star had drifted too far from its original position, on account of changes of rate or of flexure, to bring it back by the right-ascension slow motion, the observer either closing the slide of the plate-holder or following the motion of the star as best he could with the right-ascension screw. Lately a more satisfactory method, suggested by Mr. PALMER, has been employed. The slow motion in right ascension is of Grubb's form,* and the telescope has two slightly different rates, according to whether the loose wheel is stopped or allowed to turn freely. The driving-clock is adjusted so that one of these rates is too fast, the other too slow. At the beginning of an exposure the wheel is, say, unclamped, and the guiding-star begins to drift very slowly toward the left, the observer following it with the screw of the plate-holder. When it has drifted far enough, as indicated by the pins mentioned farther above, the wheel is clamped. The star then reverses its motion and begins to drift toward the right; and so on throughout the exposure. The advantages of this method over the one previously employed are, that the star never has to be moved by the slow motion of the telescope, and that its general drift is in a known direction, so that its movements can be anticipated by the observer. In this way photographs are obtained, with four hours' exposure, on which the smallest star disks are almost perfectly round near the center of the plate, and from 2" to 3" in diameter.

---

* *Mon. Not. R. A. S.*, No. 48, 352.

The star-images are practically round over a field at least 1 inch or 16' in diameter. Farther from the center they become parabolic, but they are quite good over the entire plate, 3¼ by 4¼ inches.

From these statements it will be seen that small irregularities in driving no longer present any difficulties. But certain irregular motions of the image still take place occasionally, and so far it has not been possible entirely to prevent their occurrence.

It was found that the declination clamp (the long slow-motion handle attached to which is shown in the plate facing p. 151) was not sufficiently powerful to hold the telescope firmly during a long exposure. A screw-clamp was therefore added, which forces the toothed declination sector strongly against an iron block just behind it, thus restoring, I think, the original arrangement of the declination clamp as designed by Dr. COMMON. This clamp holds the tube very firmly.

The irregularities to which I have referred consist in sudden and unexpected jumps of the image, which always occur some time after the telescope has passed the meridian. These jumps are sometimes quite large — as much as one sixteenth of an inch or 1'. They are due to two causes; flexure of the tube, and sliding of the mirror on its bed. When the jump is due to sudden changes of flexure, the image moves very quickly, and vibrates before it comes to rest in its new position, and at the same time there is often heard a slight ringing sound from the tension rods of the tube. There seems to be no remedy for the sudden motions of this class. The tension rods are set up as tightly as possible without endangering the threads at their ends or buckling the large corner tubes. A round telescope-tube made of spirally-wound steel ribbon riveted at the crossings, would probably be better than the square tube now in use.

Jumps due to shifting of the mirror are characterized by a gentle, gliding motion. They can be remedied, in part, at least, by tightening the copper bands which pass around the circumference of the mirror within its cell. This will be done the next time the mirror is resilvered.

All that the observer can do when a jump occurs is to bring back the image as quickly as possible to the intersection of the cross-wires. If all the stars on the plate are faint, no effect will be produced on the photograph; but stars of the eighth magnitude or brighter will leave short trails. The nebula, if there is one on the plate, will, of course, be unaffected.

Before beginning an exposure the focus is adjusted by means of a high-power positive eye-piece. An old negative, from which the film has been partially scraped, is placed in one of the plate-holders, and the film is brought into the common focus of the eye-piece and the great mirror. The appearance of the guiding-star, which varies somewhat with the position of the guiding eye-piece on its slide, is then carefully noted, and is kept constant during the exposure by turning, when necessary, the focusing screw of the eye-end. For preliminary adjustments a ground-glass screen is often convenient. On it all the *DM* stars, and even considerably fainter ones, as well as the nebulæ of HERSCHEL'S Class I, are easily visible without a lens.

Plates are backed, not more than a day or two before use, with CARBUTT'S "Columbian backing," which is an excellent preparation for this purpose. During the exposure the observer and assistant exchange places every half hour, thereby greatly relieving the tediousness of the work, though two exposures of four hours each, in one night, have proved to be too fatiguing for general practice. At the end of the first two hours it is necessary to close the slide and wind the clock.

The brightness of the guiding-star is a matter of some importance. If the star is too bright, its glare is annoying; if it is too faint, the effort to see it strains the eye, and changes of focus are not easily recognized. A star of the ninth magnitude is about right. In most cases a suitable star can be found without difficulty.

In such an apparatus as that described above, the amount by which the plate may be allowed to depart from its zero position is subject to a limitation which has not, I think, been pointed out, although it is sufficiently obvious when one's attention has been called to it. It depends upon the fact that the plate necessarily moves as a whole, in a straight line which is tangent to a great circle of the sphere, while the stars move on small circles around the pole. The compensation for drift, when the plate is moved, is therefore exact at the equator only.

Let the guiding-star have the declination δ_1 and let a star on the upper edge of the plate (which, when the telescope is north of the zenith, and the eye-end is on the north side of the telescope, will be the southern edge) have the declination δ_2. Then if the guiding-star is allowed to drift from its zero position through the distance d, the other star will drift through the distance $d\frac{\cos\delta_2}{\cos\delta_1}$. If the guiding-star is followed by turning the right-ascension screw, the upper edge of the plate, as well as the guiding eye-piece, will be moved through the distance d. Hence, there will be produced an elongation of the upper star, represented by

$$e = d\left(\frac{\cos\delta_2}{\cos\delta_1} - 1\right)$$

$$\text{from which } d = \frac{e\cos\delta_1}{\cos\delta - \cos\delta_1}.$$

Now, in the Crossley reflector, the upper edge of the plate and the guiding eyepiece are just about 3⅔ inches, or 1°, apart. If e is given, the above formula serves to determine the maximum range of the slide for different positions of the telescope.

It has been stated farther above that the smallest star disks, on a good photograph, are sometimes not more than 2″ in diameter, or in a linear measure, about $\frac{1}{10}^{\text{mm}}$. An elongation of this amount is therefore perceptible. There are many nebulæ in high northern declinations, and there are several particularly fine ones in about $+70°$. If, therefore, we take $\delta_2 = 70°$, $\delta_1 = 71°$, $e = 0.05$, and substitute these values, we find $d = 1.0^{\text{mm}}$, which is the greatest permissible range of the plate in photographing these nebulæ. Before I realized the stringency of this requirement, by making the above simple computation, I spoiled several otherwise fine negatives by allowing the plate to get too far from the center, thus producing elongated star-images.

There is a corresponding elongation in declination, the amount of which can be determined by an adaptation of the formula for reduction to the meridian, but it is practically insensible.

On account of the short focal length of the three-foot mirror, the photographic resolving power of the telescope is much below its optical resolving power. For this reason the photographic images are less sensitive to conditions affecting the seeing than the visual images. On the finest nights the delicate tracery of bright lines or caustic curves in the guiding-star is as clear and distinct as in a printed pattern. When the seeing is only fair these delicate details are lost, and only the general form of the image, with its two principal caustics, is seen. A photograph taken on such a night is not, however, perceptibly inferior to one taken when the seeing is perfect. When, however, the image is so blurred that its general form is barely distinguishable, the photographic star-disks are likewise blurred and enlarged, and on such nights photographic work is not attempted.

The foregoing account of the small changes which have been made in the Crossley telescope and its accessories may appear to be unnecessarily detailed, yet these small changes have greatly increased the practical efficiency of the instrument, and therefore, small as they are, they are important. Particularly with an instrument of this character, the difference between poor and good results lies in the observance of just such small details as I have described.

At present the Crossley reflector is being used for photographing nebulæ, for which purpose it is very effective. Some nebulæ and clusters, like the great nebula in *Andromeda* and the *Pleiades*, are too large for its plate (3¼ × 4¼ in.), but the great majority of nebulæ are very much smaller, having a length of only a few minutes of arc, and a large-scale photograph is required to show them satisfactorily. It is particularly important to have the images of the involved stars as small as they can be made.

Many nebulæ of HERSCHEL'S I and II classes are so bright that fairly good photographs can be obtained with exposures of from one to two hours; but the results obtained with full light-action are so superior to these, that longer exposures of 3½ or 4 hours are always preferred. In some exceptional cases, exposures of only a few minutes are sufficient. The amount of detail shown, even in the case of very small nebulæ, is surprising. It is an interesting fact that these photographs confirm (in some cases for the first time) many of the visual observations made with the six-foot reflector of the EARL OF ROSSE.

Incidentally, in making these photographs, great numbers of new nebulæ have been discovered. The largest number that I have found on any one plate is thirty-one. Eight or ten is not an uncommon number, and few photographs have been obtained which do not reveal the existence of three or four. A catalogue of these new objects will be published in due time.

Some of the results obtained with the Crossley reflector, relating chiefly to particular objects of some special interest, have already been published.* The photographs have also permitted some wider conclusions to be drawn, which are constantly receiving further confirmation as the work progresses. They may be briefly summarized as follows:—

1. Many thousands of unrecorded nebulæ exist in the sky. A conservative estimate places the number within reach of the Crossley reflector at about 120,000. The number of nebulæ in our catalogues is but a small fraction of this.

2. These nebulæ exhibit all gradations of apparent size, from the great nebula in *Andromeda* down to an object which is hardly distinguishable from a faint star-disk.

3. Most of these nebulæ have a spiral structure.

To these conclusions I may add another of more restricted significance, though the evidence in favor of it is not yet complete. Among the objects which have been photographed with the Crossley telescope are most of the "double" nebulæ figured in Sir JOHN HERSCHEL'S catalogue *(Phil. Trans.*, 1833, Plate XV). The actual nebulæ, as photographed, have almost no resemblance to the figures. They are, in fact, spirals, sometimes of very beautiful and complex structure; and, in any one of the nebulæ, the secondary nucleus of HERSCHEL'S figure is either a part of the spiral approaching the main nucleus in brightness, or it cannot be identified with any real part of the object. The significance of this somewhat destructive conclusion lies in the fact that these figures of HERSCHEL have sometimes been regarded as furnishing analogies for the figures which POINCARÉ has deduced, from theoretical considerations, as being among the possible forms assumed by a rotating fluid mass; in other words, they have been regarded as illustrating an early stage in the development of double-star systems. The actual conditions of motion in these particular nebulæ, as indicated by the photographs, are obviously very much more complicated than those considered in the theoretical discussion.

---

* The following list includes all papers of interest:—

"Photographic Observations of Comet I, 1898 (BROOKS), made with the Crossley Reflector of the Lick Observatory." *A. J.*, No. 451, 19, 151; see also *Ap. J.*, No. 8, 287.

"The Small Bright Nebula near *Merope*." *Pub. A. S. P.*, No. 10, 245.

"On Some Photographs of the Great Nebula in *Orion*, taken by means of the Less Refrangible Rays in its Spectrum." *Ap. J.*, No. 9, 133. See also *Pub. A. S. P.*, No. 11, 70; *Ap. J.*. No. 10, 167; *A. N.*, 3601.

"Small Nebulæ discovered with the Crossley Reflector of the Lick Observatory." *Mon. Not. R. A. S.*, No. 59, 537.

"The Ring Nebula in *Lyra*." *Ap. J.*, No. 10, 193.

"The Annular Nebula H. IV. 13 in *Cygnus*." *Ap. J.*, No. 10, 266; see also *Publ. A. S. P.*, No. 11, 177.

"On the Predominance of Spiral Forms among the Nebulæ." *A. N.*, 3601.

"The Distribution of Stars in the Cluster *Messier* 13 in *Hercules*," (by H. K. PALMER). *Ap. J.*, No. 10, 246.

"The Photographic Efficiency of the Crossley Reflector." *Pub. A. S. P.*, No. 11, 199; *Observatory*, No. 22. 437.

"New Nebulæ discovered photographically with the Crossley Reflector of the Lick Observatory." *Mon. Not. R. A. S.*, No. 60, 128.

"The Spiral Nebula *H. I. 55 Pegasi*." *Ap. J.*, No. 11, 1.

"Photographic Observations of Hind's Variable Nebula in *Taurus*, made with the Crossley Reflector of the Lick Observatory." *Mon. Not. R. A. S.*, No. 60, 424.

"Use of the Crossley Reflector for Photographic Measurements of Position." *Pub. A. S. P.*, No. 12, 73.

"Discovery and Photographic Observations of a New Asteroid 1899 FD." *A. N.* 3635.

"Elements of Asteroid 1889 FD.," (by H. K. PALMER). *A. N.*, 3635.

While I must leave to others an estimate of the importance of these conclusions, it seems to me that they have a very direct bearing on many, if not all, questions concerning the cosmogony. If, for example, the spiral is the form normally assumed by a contracting nebulous mass, the idea at once suggests itself that the solar system has been evolved from a spiral nebula, while the photographs show that the spiral nebula is not, as a rule, characterized by the simplicity attributed to the contracting mass in the nebular hypothesis. This is a question which has already been taken up by Professor CHAMBERLIN and Mr. MOULTON, of the University of Chicago.

The Crossley reflector promises to be useful in a number of fields which are fairly well defined. It is clearly unsuitable for photographing the Moon and planets, and for star-charting. On the other hand, it has proved to be of value for finding and photographically observing asteroids whose positions are already approximately known.

One of the most fruitful fields for this instrument is undoubtedly stellar spectroscopy. Little has been done in this field as yet, with the Crossley reflector, but two spectrographs, with which systematic investigations will be made, have nearly been completed by the Observatory instrument-maker. One of these, constructed with the aid of a fund given by the late Miss C. W. BRUCE, has a train of three 60° prisms and one 30° prism, and an aperture of two inches; the other, which has a single quartz prism, will, I have reason to expect, give measurable, though small, spectra of stars nearly at the limit of vision of the telescope.

The photogravure of the Trifid nebula which accompanies this article[*] was made from a photograph taken with the Crossley reflector on July 6, 1899, with an exposure of three hours. It was not selected as a specimen of the work of the instrument, for the negative was made in the early stages of the experiments that I have described and the star-images are not good, but rather on account of the interest of the subject. At the time the photogravures were ordered no large-scale photograph of the Trifid nebula had, so far as I am aware, ever been published.[†] The remarkable branching structure of the nebula is fairly well shown in the photogravure, though less distinctly than in the transparency from which it was made. The enlargement as compared with the original negative, is 2.9 diameters, ($1^{mm} = 13''$). The fainter parts of the nebula would be shown more satisfactorily by a longer exposure.

DESCRIPTION OF PROFESSOR KEELER'S MERIDIAN CIRCLE.

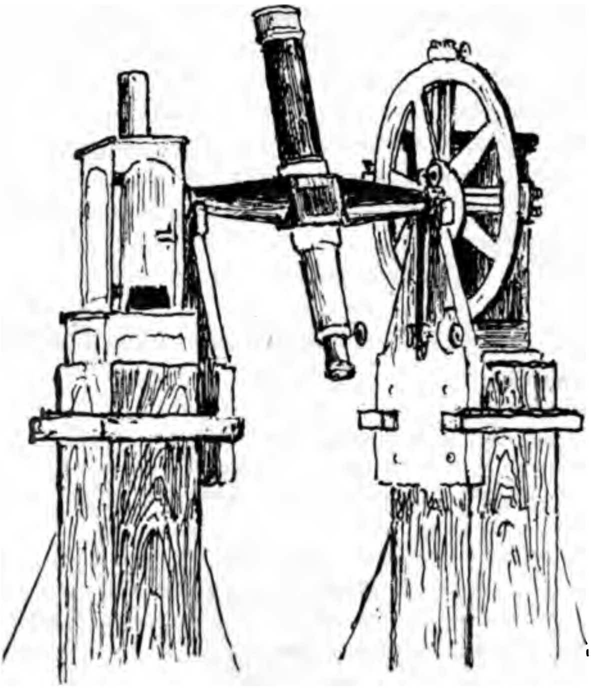
[The instrument was constructed by Professor KEELER in 1877, at which time the sketch on the next page was made. The following description of it was written by Professor KEELER in 1885.]

"The telescope of the instrument was originally part of a spy-glass. It was separated at the eye-end of the outer tube and the two parts screwed into an axis of wood (cedar), turned into the shape shown in the illustration. The pivots were formed by copper ferrules driven on and turned at the same time, as nearly equal as possible. They rested not in Y's but in semicircular bearings of brass, formed by turning an aperture in a brass plate which was afterwards cut into two pieces. The axis was rendered horizontal by a small ordinary spirit-level (no graduation), fastened on a wooden bar, having at the ends brass uprights, with (I think) square ends, to rest on the pivots. One of the brass bearings of the pivots was adjustable. The cross-wires were spider-lines cemented to a small leaden ring, movable across the field of view by the screw shown near the eye-piece, a spring being placed opposite to keep the ring pressed against the end of the screw. These wires were illuminated by a small kerosene lamp in the box shown on the left, the axis being perforated and an elliptical reflector of paper with central aperture being placed at the intersection of the telescope and axis. The circle was made of wood, fastened together in sections. . . . The graduated circle was an engraved paper protractor divided to 15′, pasted on before the central part was cut out. It was originally designed to read by two pairs of diametrically opposite verniers, but I think only one was ever finished. I do not remember what was its least count. [Possibly no vernier; only an index.] The readings are given to single minutes, perhaps, however, by estimation. The clamp with micrometer tangent screw was an improvement designed but never executed.

---

[*] Omitted here, as it has already been printed in these *Publications*. See *A. S. P. Publ.*, No. 74, p. 89.

[†] Since then a photograph by Dr. ROBERTS has appeared in *Knowledge*, No. 23, 35, Feb. 1900.



PROFESSOR KEELER'S MERIDIAN CIRCLE.

"I think the eye-piece consisted of a single convex lens.

"The piers were pieces of 6 in. × 8 in. pine sunk into the ground about two feet.

"The clock (shown behind the circle) was a small kitchen affair, and kept execrable time. It had no second-hand, and the observer made an observation by looking at the clock-face after the star was on one of the wires, mentally allowing a little for the time necessary to get up from his position at the telescope and go to the clock, and estimating the seconds as best he could.

"The instrument was protected when not in use by a cover or hood made of wood, and roofed with tarred paper, which rested upon the cleats nailed around the tops of the piers.

"To the north the horizon was invisible on account of the forest, but to the south a long sight could be obtained across the salt marsh, and a tall pine-tree nearly on the meridian served for the purposes of collimation."

A POPULAR ACCOUNT OF THE CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION TO SILOAM, GEORGIA, MAY 28, 1900.

By Charles Burckhalter.

The expedition from this observatory to observe the late eclipse was at the sole expense of Mr. John Dolbeer, of San Francisco, who also paid my salary while absent from the observatory. The lantern-slides and other work sent out since my return have also been at his expense, and there yet remains a considerable balance which he refuses to receive, thus leaving me in possession of riches I scarely know what to do with,— to me a most novel and unique experience. Mr. Dolbeer had generously settled the matter nearly a year before it was necessary for me to start; the Board of Education of the city of Oakland and Superintendent McClymonds had given me the necessary leave of absence, also granting permission to use any part of the instrumental equipment of the observatory, so that I had ample time to prepare. The above happy condition is not always realized, and many a blunder has been made because preparations had to be rushed. The very greatest care must be observed in every detail of the preliminary arrangements since the result depends upon the rapid work of a few seconds. When I shipped the instruments, six weeks before I started myself, they were as ready as I could make them. Freight is an uncertain quantity across the continent, but the instruments reached their destination about three weeks before I arrived myself.

My principal instrument was the Pierson eclipse-telescope, presented by Mr. WM. M. PIERSON to this observatory for the expedition to Japan in 1896, to which was added the duplicate lens presented by Dr. GEO. C. PARDEE for the Indian Expedition, making really a double telescope. The lenses are four inches aperture and fifteen feet focal length. A new equatorial mounting was made during my leisure time upon the same principles as that used in India, which is decribed in the Indian Report.* Some new plate-holders were added, my programme being arranged for five exposures in each telescope, if time permitted. Nine of these were to have the exposures controlled, the remaining one uncontrolled, for comparison. The proposed exposures were printed in No. 73 of these *Publications*, but the persistent grayness of the sky during the two weeks preceding the eclipse led me to change the two ten-second exposures to eight seconds, as I felt confident that ten seconds would over-expose the sky; and the result proves the wisdom of the change.

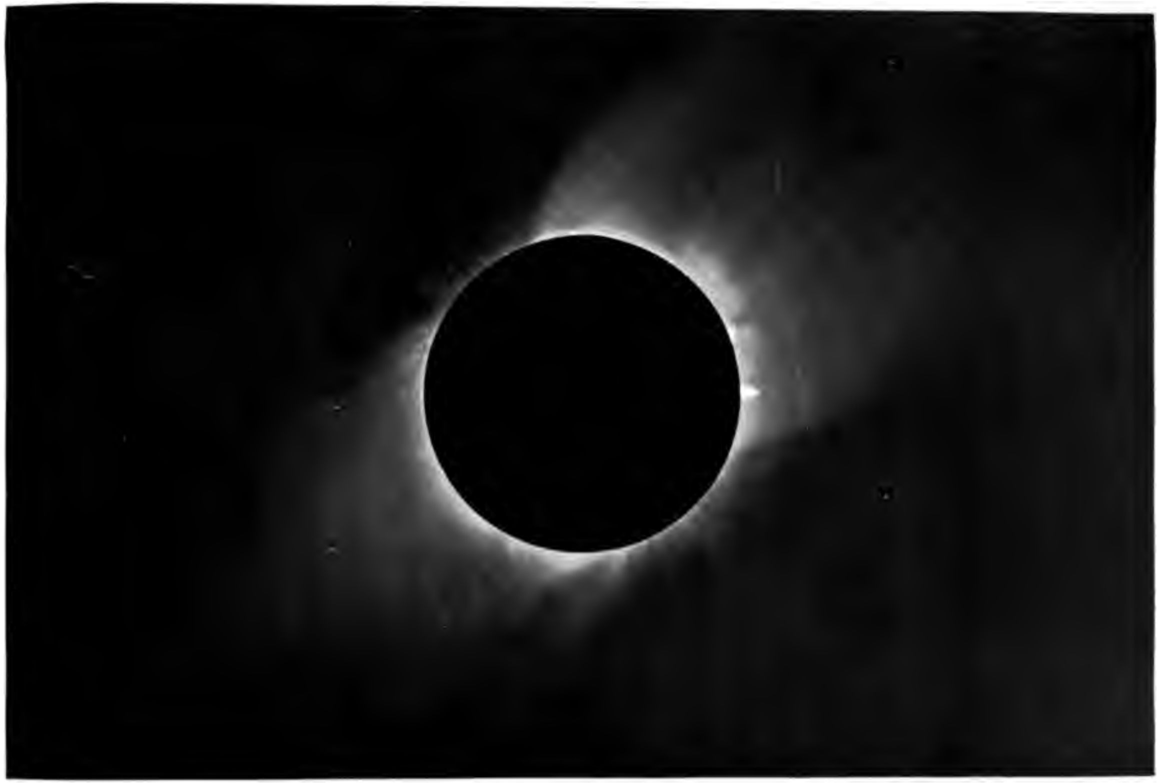
I started from home on April 24th, and had the unexpected pleasure of finding myself in the same car with Professors CAMPBELL and PERRINE, of the Lick Observatory Expedition, for the long ride across the continent.

I expected to establish the station at or near Union Point, Georgia; but upon arrival observation proved that the town was about seven miles northwesterly from the central line of totality, and I could not afford the serious loss of time this distance from the central line would cause. This was a great disappointment to me, as well as to Mr. WM. HART, and others, who had given me much valuable information, and who were also to be volunteer assistants. After some exploring to the southeast, I went to Siloam, a little village in the right direction. The maps issued by the Naval Observatory placed the village about a mile southeasterly of the central line, but preliminary observations placed it about one and one half miles northwesterly; but this gave me practically the full time of totality, and I decided to establish the station in this quiet little village, it having railroad connection, so that the instruments could be easily transferred.

The conditions of the situation selected for the station were just about perfect; a near-by empty store building—the property

---

* See also these *Publications*, No. 65.



THE CORONA, MAY 28, 1900.—NEGATIVE No. 6.

CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION, SILOAM, GEORGIA.

Exposure given, counting from Sun's center.	At—	16'	20'	24'	28'	32'	40'	50'	60'	80'	110'
		s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
	Time—	0.04	0.32	0.80	1.38	1.76	2.40	3.20	4.00	5.60	8.00

of Mr. STANLEY — was placed at my disposal, giving me a splendid place to unpack my instruments, and furnishing protection until the temporary observatory could be erected. My boarding-place was within a stone's throw. A well of good water was near by, which, with buckets and barrels always kept full, furnished protection against possible fire. Several stores and blacksmith and wagon shops, from which volunteer help to "give us a lift" could be had for the asking at any time, and, lastly, a convenient lumber-pile, to which I was invited to "help myself," completely filled all important requirements.

The readiness of the villagers to give me any help in their power was very gratifying, and fully repaid me for the idle curiosity they sometimes manifested. Many were with me much of their leisure time, and I was seldom entirely alone; but they were so good-natured and good-humored about it that I could not but let them say and do as they pleased without protest, especially as many considered this expedition "the biggest thing that ever happened to Siloam!"

The colored folk were immensely interested and impressed, the whole surrounding neighborhood, it seemed to me, coming to see and marvel. They had many curious ideas, and even some of the whites were lacking in a very deep knowledge of things "eclipse-wise." Many thought it was a money-making scheme, and what I intended to charge for admission was a very important question, frequently asked. Another idea was that the eclipse could be seen only from the inside of my observatory. I had a camera with me that at once became very popular. Requests to take their pictures were frequent, and sometimes persistent, and as all I did was "without money and without price," business would have been brisk if I had had the time to attend to it. But, taken altogether, my stay of five weeks in the village was as pleasant as one could expect while upon an eclipse expedition, which means hard work, worry, and anxiety, for the villagers fully sustained the great reputation of the Southern people for hospitality, and I received attention and favors that I had no right to expect. Just here I wish to express my appreciation of the high moral tone of the community, for, with a population of only one hundred, including the immediate neighborhood, it sustains two white and two colored churches, and during my stay I did not hear a single profane word by a citizen of this model village, situate in the heart of the "Cotton Belt."

By the kindness of J. CONKLIN BROWN, of Berkeley, who had lived for thirty years in Greensboro — seven miles distant — I was given letters that brought a perfect deluge of offers of help. With the friends at Union Point also doing all in their power to help me, this placed my enviable position in strong contrast with the lone Camp Pierson in India, where I was placed entirely upon my own resources. My greatest need seemed to be some one to help me decline the very pressing invitations I so frequently received to visit these friends at their homes.

As an unsophisticated Yankee in the Southland, unused to Southern ways, I naturally made many little slips that were not considered "just the thing." The smiles at my prefixing "Mister" to the name of my colored helper caused me to change it to "Colonel," which was entirely satisfactory to everybody, and did not materially increase the number of colonels. As he reminded me of my faithful Indian cook, Mustapha, his full and official title is now "Colonel Mustapha Berry Evans," and he now enjoys among his friends the reputation of being an astronomer of no mean ability.

Within a week the telescopes were in rough position, my observatory, sixteen by twenty-four feet floor-space, and eight to twenty-two feet high, was completed, and I was ready for the worst part of the work — the little things. The weather and sky were superb, everything seemed to prosper, and I began to look about for assistants; for I had undertaken the expedition alone. These were chosen from among the people of the village. I had received several offers of help from Atlanta, Athens, and other towns; but I needed assistants close at hand, in order to have them practice their parts often, skill being of more importance with me than knowledge. Besides, I did not have to *unlearn* them. They were clerks, merchants, blacksmiths, and farmers by occupation. Their work was simple, yet the success of the expedition rested largely upon them, for I could not have accomplished one half the programme by myself; and the fact that the entire programme went through without a hitch, proves how faithfully and well they did their work. We had many rehearsals, — two during daylight, the remainder at night, each time going through the full programme several times, just as we expected to do on eclipse day. There were two men trained for each important place and an extra man for emergencies.

The weather, that overshadowing question at eclipses, became unsettled about the 18th, and my records show that I had only about one chance in ten for clear weather — and I have since heard that there were but two clear days in the following six weeks! We had some severe thunder-storms with heavy wind. One squall made the buildings in the village crack, and I feared for a time for the safety of the temporary observatory; but it gallantly rode out the storm, a thorough soaking to my bed and some books being the only damage.

On eclipse day the sky was about three tenths cloudy near the eastern horizon, the wind was southeast, drifting the clouds toward me, and for a time I felt intensely anxious; but by first contact the sky was nearly clear, my only fear being that the drop in temperature would chill the moisture-laden air again. I had an hour of doubts and fears; but the sky remained clear, but very gray, which confirmed me in my determination to cut my two ten-second exposures to eight seconds.

The programme went through perfectly. Not a word was spoken except the ones agreed upon. Each one had an opportunity for a short glance at this, Nature's greatest phenomenon; and just four seconds after the last exposure was completed a beam of sunlight brilliantly proclaimed that the eclipse was over. It began clouding up immediately, and we had "a right smart" sprinkle before noon, which I observed with genuine satisfaction, for the long strain and anxiety had ended with totality.

Two plates were developed at once in the closet under the stairs of Mr. Fillinghim's house; the remaining eight were taken to Professor Barnard, at Yerkes Observatory, and to Secretary Ziel, at home, for expert development. The two plates developed had received extremes of exposure for the inner corona, and as they were respectively slightly under and over exposed, as I had hoped, I knew the plates with intermediate exposures, upon which my hopes were centered, would be all right. So I began packing up the instruments, leaving the village four days later, thus breaking my best record in packing up.

The results obtained will be more fully discussed in the forthcoming report, and the following description of the more characteristic negatives must suffice here.

No. 1 is a curiosity in at least one respect — the extreme inner corona is thoroughly *under-exposed.* At the Moon's edge the exposure was only $0^{s}.02$. The prominences seem to have been perfectly exposed, being full of delicate detail, the chromosphere was over-exposed, while the corona is so faint that by hard printing it can be printed out entirely, leaving only the prominences and chromosphere.

No. 5 was exposed eight seconds without control, for I wanted one uncontrolled plate to compare with the others.. It is an excellent negative, but shows nothing whatever near the Moon's limb.

No. 6 was made during the same interval, receiving precisely the same total exposure as No. 5. These plates are, therefore, strictly comparable. The exposure of No. 6 at 16′ from the Sun's center was $0^{s}.04$, thus giving the corona at 110′ distance two hundred times more exposure than at 16′. This is my second-best negative, the printing qualities being exceptionally good.

No. 7 shows a greater extension on the eastern side of the Sun than any other plate. It can be traced with certainty to 84′. The exposure at 16′ was $0^{s}.08$ — too much for best results. It shows all the prominences, but not in such detail as other plates.

No. 8 is very much the best negative from a scientific standpoint, but unfortunately it has some specks on the film, and besides has been somewhat over-developed. It is a hard printer, and, so far, I have not been able to obtain results that are reasonably satisfactory.

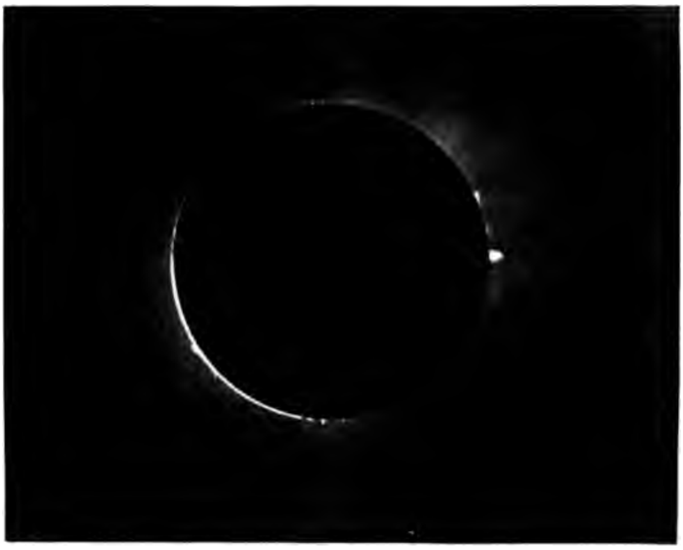
No. 9 and No. 10 have exquisite inner detail, but not such good extension.

For the Pierson telescope, using Cramer crown plates, $0^{s}.04$ to $0^{s}.05$ was the proper exposure for the extreme inner corona, and $8^{s}.00$ gave me the best extension. On the Chabot Observatory-Pierson expedition to India, the shortest exposure was $0^{s}.08$. The Indian corona was much brighter than the recent one, and $0^{s}.03$ would have been about right there, but such an exposure with a four-inch lens with fifteen feet focus would have been thought ridiculous at that time. While the shortest Indian exposure was about three times too much for best results, it gave me the very knowledge I needed to make the Georgia expedition a success. I asked advice from no one this time, but used my own judgment, No. 8 being my ideal plate. The exposure, it seems to me, is precisely right in every part.

I cannot close this article without grateful acknowledgments to the Southern Pacific Company, for half-rates on freight, and to Mr. HORSBURGH, of the Passenger Department, for half-rates of fare; also to the Northern Pacific Railway and the Pacific

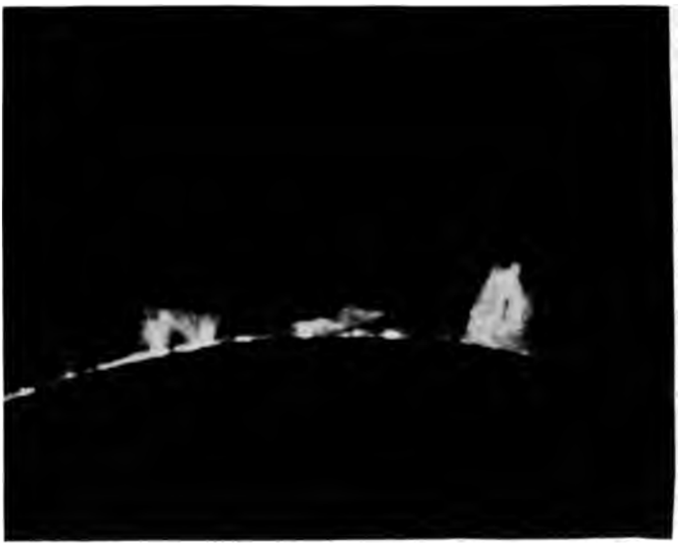
THE CORONA, MAY 28, 1900.

CHABOT OBSERVATORY-DOLBEER ECLIPSE EXPEDITION, SILOAM, GEORGIA.



From Negative No. 1, from 0 to 4th second of totality:

Exposure given, counting from Sun's center.	At —	16′	18′	20′	24′	28′
		s.	s.	s.	s.	s.
	Time —	0.02	0.08	0.18	0.42	0.78



Part of Negative No. 10, six seconds exposure, from 77th to 82d second (inclusive) of totality, from a print made from a negative, made from a positive enlarged 6 diameters:

Exposure given, counting from Sun's center.	At—	16′	18′	20′	24′	28′
		s.	s.	s.	s.	s.
	Time —	0.06	0.12	0.25	0.62	1.16

Coast Steamship Company, for half-rates over their lines. In fact, it were better to thank every person with whom I came in contact, for without exception I was helped by everybody that could help me. I wish to express my appreciation of the kindness received from Judge HART and his nephews, WILLIAM and H. B. HART, of Union Point, and to thank Mr. LITTLE, Mr. ROSSMAN, and many others of Greensboro for their splendid hospitality. My stay in the Sunny South was made so pleasant that the name of Georgia is synonymous with friendship, hospitality, and good-will.

The following assistants have placed me under obligations and aided science: J. T. BRYSON, D. A. SAGGUS, J. M. SAGGUS, H. H. ANDREWS, A. S. ONEAL, W. J. ONEAL, E. J. STANLEY, JNO. T. BOSWELL, CLAY FILLINGHIM, all of Siloam; and Mrs. ROBINSON, of Greenboro, who made drawings of the corona.

Finally, I must not forget "Colonel Mustapha" Berry Evans, the colored wag of the village, who carries the mail from the post-office to the station four times a day for less than three dollars a month, but manages to make his living with less work than any man in the neighborhood. He was my helper throughout. There is a smile in the story of how he would have assisted me more if I had applied to him in time. I was making sextant observations for position one night, and this aroused his curiosity. In answer to his question of what I was doing, I told him I was trying to find out exactly where I was. His amazement and pity for my ignorance found expression in "Foh de Lawd's sake! why did n't you ask me? I was done bo'n and brought up heah! You 's *right heah in Siloam.* I reckon you 's foolin' me!"

CHABOT OBSERVATORY, OAKLAND, CAL., September, 1900.

THE CROCKER EXPEDITION TO OBSERVE THE TOTAL SOLAR ECLIPSE OF MAY 28, 1900.

BY W. W. CAMPBELL AND C. D. PERRINE.

The generosity of WILLIAM H. CROCKER,* of San Francisco, enabled the Lick Observatory to send an expedition to observe the total solar eclipse of May 28, 1900. The organization of the expedition was begun by Professor KEELER, Director of the Observatory, at the middle of March. The members of the staff detailed for this duty were the writers of this article. The preparations of the instruments and equipment were necessarily very hurried, but Professor KEELER placed the resources of the Observatory at our disposal, and the heavy packages were ready for shipment on April 11th. However, several new prisms and lenses ordered from the Eastern makers arrived so late that the three new spectrographs could not be completed before the shipment was made. They were finished at the station, only a day or two before the eclipse. The observers left San Francisco on April 24th, via El Paso and New Orleans.

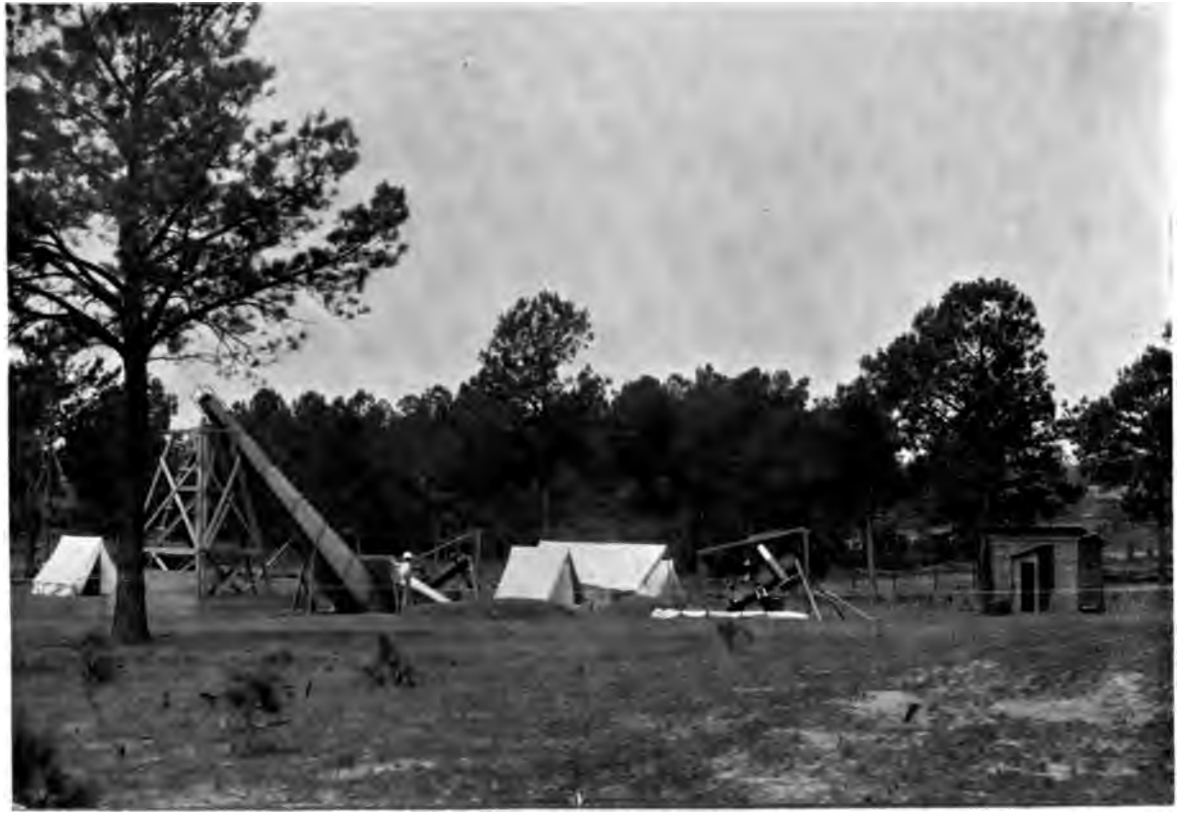
---

* Mr. CROCKER's brother, the late Colonel C. F. CROCKER, Regent of the University of California, had similarly befriended the Lick Observatory, in the Expeditions sent to Cayenne in 1889, to Japan in 1896, and to India in 1897–98.

The path of totality began at sunrise in the Pacific Ocean, swept across Mexico, the southeastern portion of the United States, the Atlantic Ocean, Portugal, Spain, and Algiers, and ended at sunset in southeastern Egypt. Observations in the elevated regions of Mexico were precluded by the low altitude of the Sun; and the path available in the United States for occupation by an observing party lay along the line joining New Orleans, Louisiana, and Norfolk, Virginia. The cloud observations secured in May and June of the three preceding years by the Weather Bureau, indicated that the chances for clear sky were best in eastern Alabama and western Georgia, where the foothills of the mountains reach nearly to the shadow-belt, and where the height of the station above sea-level would be the greatest. Stations to the east of this locality would have the compensating advantage of a higher Sun. As the eastern observatory parties would probably select stations well to the east, it was decided that our party should locate in western Georgia, at the city of Thomaston.

The observers reached Thomaston on the evening of April 30th, and were warmly welcomed by the Mayor, the County School Commissioner, and other prominent citizens. The next forenoon, in company with these gentlemen, we were driven over the surrounding country — beautiful rolling country, grown over with forests of pine and oak, or just sown with cotton-seed — in search of a suitable camp. A site was selected in an open field, gently sloping to the west, about one half mile northwest of the city, but still within the city limits.

The preparation of the camp began at once. Relegating the carpentry, masonry, and excavating as far as possible to local



GENERAL VIEW OF THE OBSERVING-STATION OF THE CROCKER ECLIPSE EXPEDITION, THOMASTON, GEORGIA.

workmen, our own time was very fully occupied, up to the last minute, with completing, mounting, and adjusting the instruments, and in training the assistants to the programme of observations.

The 40-foot photographic telescope was mounted almost precisely as it was mounted in India in 1898. A wooden tower, pyramidal in form, was constructed to support the 5-inch lens. A larger tower of the same form surrounded the lens-tower, so that, when covered with canvas on the morning of the eclipse, the wind could not vibrate the inner tower and the lens. The outer tower also supported the upper end of the canvas tube of the camera. The lower end of the canvas tube, the steel track for the traveling plate-holder, and the clock were in a pit excavated in the red clay soil to a depth of about nine feet. A large canvas sheet covered the pit and its approaches, to keep the rain from entering it.

The four spectroscopes and one medium-sized camera were mounted on a large polar axis, driven by a clock placed at the end of a sector 10½ feet in length.

Two medium-sized photographic telescopes and four small cameras were mounted on another polar axis, driven by a clock at the end of an 8½-foot sector.

Brick piers extending to a depth of two feet were constructed to support the polar axis; and similar piers served to support the chronometer and the sextant basin of mercury. The soil under the camp transmitted vibrations with but little loss of strength. It was impossible to make sextant reflection observations if any person was walking within twenty-five or thirty yards of the observer.

A very complete dark room, six by ten feet, with water-pipes for supply and waste, was constructed.

Sextant observations of the Sun and of the stars, for determining the latitude and longitude of the camp, were secured soon after our arrival. Thomaston is situated at the end of a branch line of the Central of Georgia Railway; and the regular time-signals do not go over this branch. At our request, the officials of the Western Union Telegraph Company transmitted the signals of the U. S. Naval Observatory clock in Washington daily to Thomaston, for comparison with our local time. As a result of six days' observations, and telegraphic comparisons, the longitude of the station was found to be

$$5^h\ 37^m\ 18^s.8 = 84^\circ\ 19'.7.$$

The observed value of the latitude is + 32° 53′.7.

These values are approximate, since the final reductions have not been completed. The station was one half a mile northwest of the central line assigned by the American Ephemeris, and very close to the British Almanac line.

As in other recent expeditions sent out from here, dependence was placed on volunteer observers to take the greater number of the photographs. Seven astronomers from a distance volunteered to serve, at their own expense, and seven additional assistants from Thomaston offered their services. These gentlemen were: Professor Dr. A. A. NYLAND, Director of the Utrecht Observatory, Utrecht, Holland; Dr. J. H. WILTERDINK, Astronomer in the Royal Observatory, Leiden, Holland; HEBER D. CURTIS, Professor of Mathematics and Astronomy in the University of the Pacific, San José, Cal., and now Fellow in Astronomy in the University of Virginia; JOHN A. MILLER, Professor of Astronomy in the University of Indiana; W. P. RUSSELL, Professor of Astronomy in Lincoln University, Lincoln, Illinois; A. H. BUCHANAN, Professor of Mathematics and Astronomy in Cumberland University, Lebanon, Tenn.; G. E. LUMSDEN, Esquire, President of the Toronto Astronomical and Physical Society; Captain J. R. ATWATER, Mayor of Thomaston; Dr. EUGENE T. BOOTH, of Thomaston; Professor REMBERT G. SMITH, President of the R. E. Lee Institute, Thomaston; Professor GEORGE K. ORR, of the Lee Institute; Professor JOSEPH E. HANNAH, Col. JOHN H. LEWIS, and ALBERT A. MATTHEWS, Esquire, of Thomaston.

We wish to acknowledge very fully the able and faithful services rendered to the expedition by these assistants. They multiplied the quantity of useful results obtainable several fold.

The assistants were drilled on the three days preceding the 28th, until every man felt confident that he could carry out his share of the programme, in the eighty-five seconds of totality. The delicate parts of all the instruments were examined, and all the adjustments were tested, so far as possible, on the day before the eclipse. The Weather Bureau predicted unusually favorable atmospheric conditions for the eventful morning along the entire line of totality. The night of the 27th was devoted to "backing" the plates and filling the plate-holders, and the sky was beautifully clear, at least up to 3:00 A.M. On rising for the day's work, at 4:00 A.M., the sky was completely clouded!

The clouds were gradually dispelled by the heat of the Sun, until at the time of first contact, the sky was nearly clear. Sextant observations for time were secured, and reduced; and, a light breeze springing up, the wind-screens were placed on the tower, and on the windward side of each polar axis. Five or ten minutes before totality the instruments were directed to the Sun and the clocks started, and the assistants took their places. Attention was called to the large masses of clouds rapidly approaching from the southwest. Up to two or three minutes before totality, it seemed certain that the corona would be completely hidden; and up to one minute thin clouds threatened to cut off portions of it. Fortunately, there was time to secure the observations; and about one minute after totality the clouds obscured the Sun. The state of the air had been such that the lowering of its temperature as the eclipse came on was sufficient to form clouds. In another half-hour these had disappeared; and a second set of time observations were secured just after the last contact. The sky throughout the morning was quite white.

The programme of observation, with the eleven instruments, and by two visual observers, was completely carried out, except that on one of the spectroscopes a clock for giving uniform motion to the plate-holder refused to work just at the beginning of totality. However, it was quickly righted, and the desired long exposure to the corona spectrum during totality, and the exposure with moving plate-holder at the end of totality, were secured; so that only one-third of the work with this instrument was lost.

Owing to the great distance from the Lick Observatory, we could not follow the practice of the Eastern parties in taking the plates home for development in cool dark-rooms. It was necessary to develop at Thomaston. The week following the eclipse was very hot, both day and night. The dark-room was uninhabitable by day; but after ten o'clock at night, by the liberal use of ice, the temperature of the room could be brought down to between seventy and seventy-five degrees; and the development was carried on between that hour and daylight.

As a result of this expedition, the Observatory possesses a large number of very beautiful and very valuable photographs of the eclipse phenomena, as well as several valuable results obtained from the visual observations.

The ninetieth-meridian times of beginning and ending of the total phase for the position of the station, as computed from the

American Ephemeris data by Messrs. PERRINE and CURTIS, were—

for beginning, May 28th, $7^h\ 38^m\ 17^s.3$ A.M.
for ending, 7 39 42.2 A.M.

The computed duration was $1^m\ 24^s.9$.

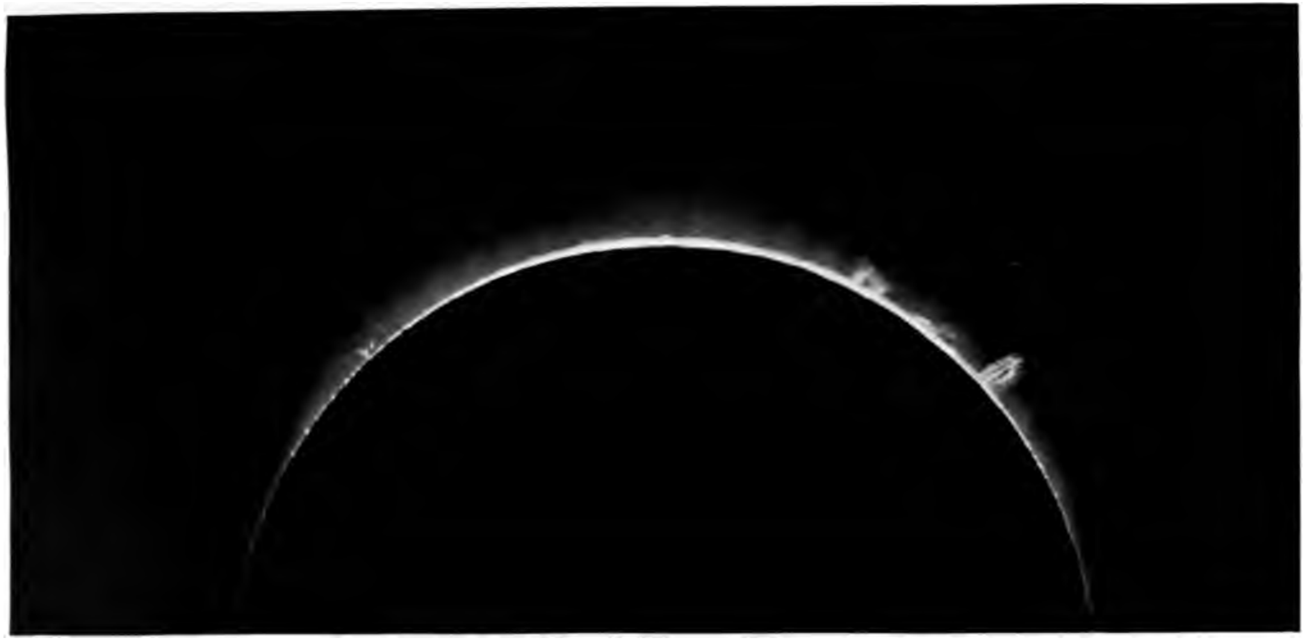
The duration as observed by Mr. PERRINE, in the camera-end of the 40-foot telescope, was $1^m\ 23^s.7$; and by the naked-eye observers it was certainly more than $1^m\ 25^s$, and may have been as much as $1^m\ 27^s$. The signal "Go" was given by Mr. PERRINE, at the instant of totality, as a signal to the man at the chronometer to begin the counting of seconds aloud, as a guide to the observers. The signal did not refer to the instant when the crescent of light disappeared, but to an instant—possibly one and a half seconds later—when the last points of light, shining evidently through the depressions in the Moon's edge, vanished completely. At the end of totality, the first points of returning light were visible to Mr. PERRINE after a duration of $1^m\ 23^s.7$. To two naked-eye observers—Messrs. CURTIS and RUSSELL, detailed for this purpose—the light, probably the crescent of sunlight, returned at $1^m\ 25^s.3$ after the signal "Go." It is probable, therefore, that the interval between the disappearing and reappearing crescents was about $1^m\ 27^s$. At any rate, it is certain that the signal given by Mr. PERRINE, for the disappearing points of light, was perceptibly later than the instant when, to the naked eye, the eclipse seemed to be total.

The times of beginning and ending noted by Mr. PERRINE were—

$7^h\ 38^m\ 10^s.1$ A.M.
7 39 33.8.

The total phase, therefore, occurred between seven and eight seconds earlier than the time assigned by the Ephemeris.

Eight photographs were secured with the 40-foot telescope during totality, on Seed's No. 27 plates, single-coated and "backed," with exposures varying from half a second to sixteen seconds. They are of great excellence. The structure of the prominences, the thick chromospheric stratum, and the coronal streamers are beautifully shown. The hoods of streamers inclosing the prominences, so remarkable a feature on the Indian coronal photographs of 1898, are not conspicuous on the present photographs, though certainly present in the case of one prominence of medium size. There are several minor indications of a connection between



THE PROMINENCES, CHROMOSPHERIC LAYER AND EXTREME INNER CORONA, ON THE WEST SIDE OF THE SUN.

(Exposure One-Half Second, Near the End of Totality.)

CROCKER ECLIPSE EXPEDITION, THOMASTON, GEORGIA.

the prominences and the streamers; but further evidence must be secured at future eclipses, before the question will approach solution.

A number of fine small-scale photographs of the corona were obtained with the shorter telescopes, suitable for studying the details and forms of the streamers in the regions of medium brightness.

Several of the shorter cameras were devoted to a determination of the conditions best adapted to recording the faint outer streamers of the corona. Several varieties of plates — single and triple coated, slow, medium, and rapid — and exposures from short to very long, were tried. It had seemed to us that the question of recording the outer extensions was one of contrast; and that slow plates, with normal exposure and full development, would give the best promise of success. The results justified this conclusion. The greatest extensions, about four solar diameters on the west side, were secured with a camera whose ratio of aperture to focus was 1 to 3½, and an exposure of twenty seconds on a lantern-slide plate. The inner corona, as was expected, was very much over-exposed. Visual observations of the corona by Messrs. LUMSDEN, BUCHANAN, CURTIS, MILLER, and HANNAH agreed very well in placing the lengths of the visible streamers on the west at about 3 or 3½ diameters, and somewhat shorter than this on the east.

The objective-prism spectrograph, with two 60° prisms in front of a 2-inch aperture and 60-inch focus objective, furnished a fine photograph of the bright- and dark-line spectra of the Sun's edge at the end of totality, as the edge was gradually uncovered by the Moon. This is on a plate moved by the clock which refused to run at the beginning of totality, referred to above. This plate, limited in size by the construction of the instrument, extends from a little below the *b* group to a little above *K*. It contains about 600 bright lines, sharply in focus, as well as the dark-line spectrum to which the bright lines gave way as the Sun reappeared. It is about six inches in length.

A 20-second exposure on the spectrum of the corona, with the same instrument, records the prominences in their principal chemical elements, as well as the two coronal rings at λλ 369 and 423.

The structure of the green coronal ring, on the west side of the Sun, as recorded by an objective grating spectrograph, agrees, in general, with that of the ring as photographed with the same instrument in India. The coronal material radiating the green light is heaped up in the sun-spot regions very markedly. The position of the ring is λ 5303±, as determined from the Indian plates. The eastern half of the ring was not recorded.

A photograph of the spectrum of the inner corona, taken with a slit spectroscope, is free from dark lines, as in the case of the Indian photographs.

Very interesting and successful observations of the shadow bands were made at the beginning and ending of totality by Messrs. BUCHANAN and LUMSDEN. White sheets were stretched on the ground, on which the bands were well observed. The directions of the bands were fixed by placing long rods of wood on the sheets, and adjusting them, during the second of time that the bands lasted, to the proper direction. The positions of the rods were afterwards determined to be:—

For the beginning,	N. 37° W.,	by Professor BUCHANAN.
For the ending,	N. 42° W.,	by Professor BUCHANAN.
For the ending,	N. 39° W.,	by Mr. LUMSDEN.

The bands were traveling toward the northeast. These gentlemen also secured very satisfactory drawings of the outlines of the corona.

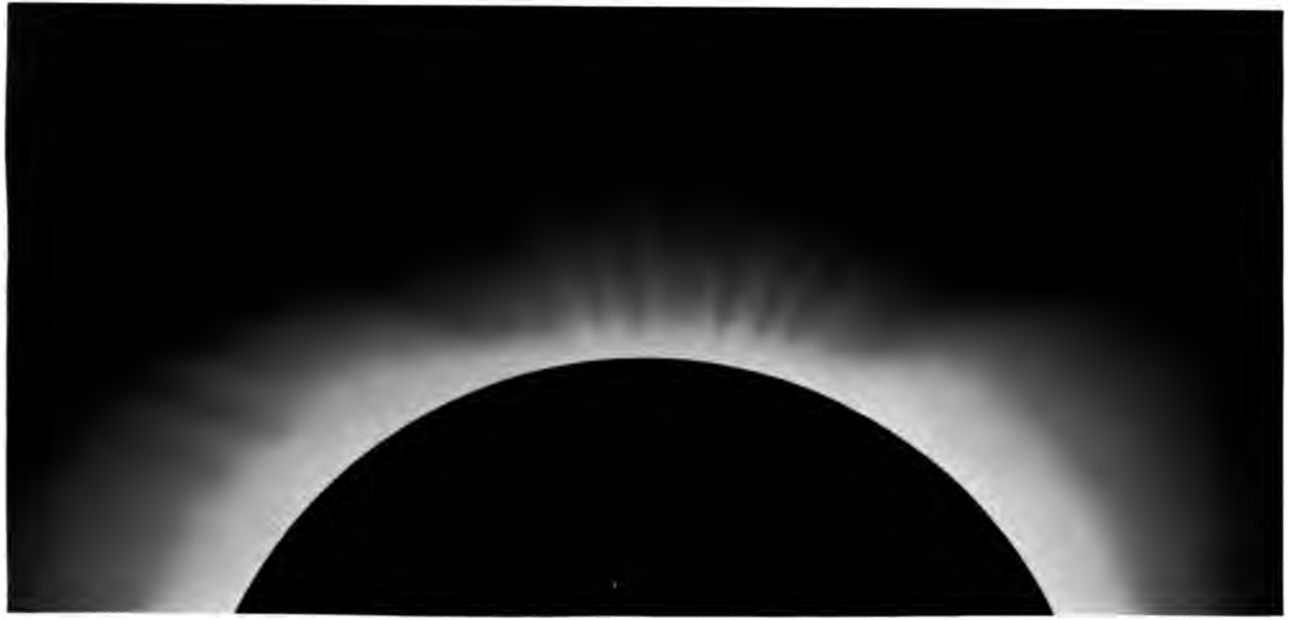
The sky seemed slightly brighter during totality than at the Indian eclipse. There would have been no difficulty in reading ordinary print.

Portions of two of the large-scale photographs of the corona are reproduced to accompany this article. It should be said that the finer details of the photographs are almost entirely lost in the process of reproduction. There appears to be no known way in which such pictures can be satisfactorily copied by mechanical processes.

It will be understood that the foregoing account of the work of the expedition is of a general nature. The detailed study of the photographs and of the individual observations will be made as soon as possible, and the scientific results will be published later.

The expedition received valued favors from many sources, which we gratefully acknowledge.

The Southern Pacific Railway Company assisted the expedition in every possible manner. We are especially indebted to General Passenger Agent T. H. GOODMAN; General Freight Agent Wm. SPROULE; the officials of the freight offices in San



THE NORTH POLAR STREAMERS OF THE CORONA.
(Exposure 16 Seconds, with the 40-foot Camera.)
CROCKER ECLIPSE EXPEDITION, THOMASTON, GEORGIA.

José and New Orleans. When the instruments were detained a week in New Orleans by the floods, and a dangerous delay was threatened, the kind offices of the Company were exerted to secure their shipment on the first train leaving the city for Atlanta.

Scarcely second in importance were the favors extended at every opportunity by the officials of the Central of Georgia Railway. We recall with pleasure the assistance afforded by President J. M. EGAN; by General Passenger Agent J. C. HAILE; by Col. D. W. APPLER, in charge of the company's interests in Atlanta; by Traveling Passenger Agent WARREN H. FOGG; and by Agent WHITE, at Thomaston.

The success of the expedition was promoted in every possible manner by the officials of the city of Thomaston, by the officials of Upson County and by the leading citizens. Hon. JAMES R. ATWATER, Mayor, made it a daily duty to inquire after our needs, and to supply them as far as possible, and promptly. Captain ATWATER'S constant thoughtfulness and helpfulness will not be forgotten. Among the special services rendered by the city, through its worthy Mayor, we may mention that excellent special watchmen were furnished for the camp, without expense to us. This service was executed in a satisfactory manner, and not even a nail was missing at the end of our five weeks' residence. City Marshal MCDANIEL assisted us very efficiently in many ways. The genial night-watchman, Mr. HAINSBERGER, was thoughtfully helpful on many occasions.

The Hon. R. D. SHUPTRINE, County School Commissioner; Dr. HERRING, County Trustee and citizen; and many other leading members of the community rendered services which will be gratefully remembered.

Professors MILLER and RUSSELL were constantly at the station during the three days preceding the eclipse, and were very efficient assistants in completing many of the minor mechanical details.

We desire to make special acknowledgment of the voluntary services rendered by Professor CURTIS. He was with us ten days. He assisted in the final installation of the instruments. He was placed in charge of the polar axis carrying the six cameras, and at the head of the observing party operating them. We do not see how we could have dispensed with his services, nor how any one could have met the exacting demands better than he did.

It may not be out of place to refer to the complex requirements of a successful eclipse expedition. The installation of a dozen instruments in a permanent observatory, with skilled and technical assistance available, so that all the instruments will work well when required, is not a simple matter. The dozen instruments at a temporary eclipse station, where skilled assistance is not available, must work equally well ***at a given second of time.***

After our eclipse duties were over, we visited, with pleasure and profit, the most of the leading observatories of the country, and attended the annual meeting of the Astronomical and Astrophysical Society of America, in New York; returning to the Lick Observatory in the last week of July.

OBSERVATIONS OF THE ZODIACAL LIGHT FROM JANUARY, 1899, TO JULY, 1900.

By Francis J. Bayldon, R. N. R.

(abstract.)*

I. General Remarks.

All observations were made at sea. From January to August, 1899, our voyages were from Sydney to Wellington (N. Z.), Suva (Fiji Is.), Honolulu, Victoria (Vancouver Is.), and Vancouver (B. C.). Since August, 1899, the voyage is from Sydney to Brisbane (Queensland), Honolulu, Victoria, and Vancouver. The round voyage from Sydney to Sydney takes nine weeks, including two weeks' stay at Vancouver. In Sydney we remain for three weeks. If necessary, the average speed of the ship may be considered as fourteen knots per hour.

From January to August, 1899, the observations were chiefly made during my watch on deck from 8 to 12 P. M. aboard the R. M. S. *Aorangi.* From August to the present time they have been made from 7 to 9 P. M., and from midnight to 4 A. M. aboard the R. M. S. *Warrimoo.*

---

*Mr. Bayldon's paper is too extensive to be printed in full in our ***Publications.*** With his consent, we therefore present this abstract, which gives in full the notes made on a few nights. The original paper is on file in the library of the Society.—The Committee on Publication.

The star-charts chiefly used are PROCTOR'S "Small Star Atlas," and an old "Celestial Atlas" by JAMIESON, published at the beginning of the century. As both outlines and the line of central axis are given, it is hoped that any clerical errors or mistakes will be easily recognized.

A great many of the observations were corroborated by officers or passengers who happened to be handy. Observations of the Light are very rare in the Pacific between November and April on account of the great amount of cloud then present.

Latterly, I have endeavored to form some idea of the intensity of the Light by imagining a table of intensity, ranging from 1 = Light just visible as a diffused glow, outlines unobtainable, to 10 = very bright, equal to the brightest portions of the Galaxy, *at their brightest.*

II. OBSERVATIONS.

1899. January 9th—Lat. 13½° S.; Long. 177° W.

8 to 10 P. M.—Very clear night. Light very distinct, considerably brighter than the Galaxy. The western cone very bright to an elongation of about 105°. Diffused light widely extended on both sides. Beyond the apex, diffused light appeared alternately nearer the *Pleiades*, and α and β *Arietis*, and *Aldebaran* and α and γ *Ceti.*

In *Sagittarius*, *Capricornus*, *Aquarius*, and *Pisces*, the line of central axis lay from 4° to 0° south of the ecliptic, the breadth of the Light ranging from 30° at an elongation of 30°, to 12° at elongation 105°.

In *Aries* and *Taurus* the line of central axis lay from 0° to 1° north of the ecliptic, the breadth of the Light varying from 12° to 8° at elongation 140°. The Gegenschein distinct from near Σ to β *Geminorum*, oval-shaped, but the glow of *Mars* completely spoils observations.

February 1st — At Comox, Vancouver Island, Lat. 49½° N.; Long. 124° W.

8 P. M. to 11:30 P. M.— Very clear, frosty night. Thermometer 20° F. Magnificently clear air. The western cone as bright as the Galaxy in *Perseus*, extending to the *Pleiades*, about 65° altitude, 20° broad in *Aries*, lower portion apparently enormously displaced to the northward in *Andromeda* and *Pegasus*, but land interfered with observations at a low altitude, as did the Galaxy and *Mars* at very high ones. The Light was distinctly

visible from the Gegenschein to near the eastern horizon below the Sickle. Apex of western cone at 105° elongation. At 11:30 clouds formed and the glow of Aurora Borealis appeared to the northward. Outlines of the Light were obtained as follows:—

NORTHERN BOUNDARY.	LINE OF CENTRAL AXIS.	SOUTHERN BOUNDARY.
2° N. of γ *Pegasi.*	δ *Piscium.*	ι *Ceti.*
α *Arietis.*	ε *Arietis.*	2° S. of ξ′ "
5° N. of *Pleiades.*	*Pleiades.*	1° N. of μ *Tauri.*
	β *Tauri.*	
[Galaxy intervenes.]		
½° N. of α *Geminorum.*	1° S. of ι *Geminorum.*	δ *Geminorum.*
Gegenschein.		
Near μ *Leo Majoris.*	1° S. η *Leo Majoris.*	ο *Leo Majoris.*
" ζ " "	Just N. of β *Virginis.*	3° N. of η *Corvi.*
β " "	2° N. of α "	4° N. of γ *Hydræ.*
3° N. of δ *Virginis.*		
Just N. of ζ "		

Diffused light apparently extended through *Triangula* about to β *Andromedæ* and wholly embraced the Square of *Pegasus.*

May 9th— Lat. 33° N.; Long. 147° W.

10:45 to 11:15 P. M.—Magnificent observations. Light faint, but distinctly outlined. Western branch just touches *Virgo.* Rising Galaxy humbugs eastern horizon. Night very clear. Outlines as follows:—

NORTH.	CENTRAL AXIS.	SOUTH.
1° N. of α *Geminorum.*	Just N. of ι *Geminorum.*	δ *Geminorum.*
ε *Leo Majoris.*	" S. of β "	2° S. of *Præsepe.*
1° N. of γ " "	η *Leonis.*	1° S. of α *Leonis.*
3° S. of θ " "	1½° N. of σ "	τ "
2° S. of π *Virginis.*	1° N. of β *Virginis.*	2° S. of β *Virginis.*

June 28th—Lat. 14° S.; Long. 177° W.

Apparently clear sky, but as cirrus haze was prevalent during the day, presume it is also about to-night, especially as stars are not very bright. Slight cumulus at times. From 7 to 9 P. M. western cone appeared narrow, with hard outlines, especially to the southward, and no diffused light was seen. At times it nearly equaled the Galaxy, at times rivaled stars of the third magnitude. Only the concentrated bright central portion was visible. Not visible beyond *Jupiter*. At 10 P.M. the central axis appeared 1° more southerly. The southern boundary then extended nearly to δ *Corvi*, the northern to δ *Virginis*.

At 11:15 P. M. the Moon rose, making cirrus streaks apparent.

June 29th — Lat. 9° S.; Long. 175° W.

Cirrus haze and cumulus, with occasional showers and bright, clear intervals. Light observed from 7 P. M. to midnight. Light was bright, extending to the zenith, but gradually faded as the night progressed, particularly to the northward, thus throwing the line of central axis more southerly. No trace of Light beyond *Jupiter*. Moon rose about midnight. Between 7 and 9 P. M. boundaries were noted as follows:—

NORTHERN.	CENTRAL AXIS.	SOUTHERN.
2° N. of μ *Leo Majoris*.	From about *Præsepe*	ζ *Hydræ*.
Just S. of β " "	Just N. of α *Leonis*.	4° N. of μ *Sextantis*.
δ *Virginis*.	" S. of χ "	Midway θ *Crateris*. ε "
Jupiter.	1° S. of β *Virginis*.	η *Corvi*.
	α "	7° S. of α *Virginis*.

REMARKS—*June 28th, 29th, 30th.*

Thin cirrus haze and streaks prevalent throughout each day, and therefore during the nights. They give the Light a hard, apparently true outline, no diffused light either above cone or on either side being visible. The cone generally appears long and narrow, but by continued watching the utmost extent can be obtained — first one boundary, then the other. At times, as one side may be curtailed more than the other, the line of central axis appears to move about, and the true position is only derived by taking the utmost boundaries derived from time to time. If the cirrus streaks lie east and west, it is very hard indeed to distinguish between them and the actual Light. Cirrus haze is frequently unnoticeable when over the bright center of Light, except as it tends to equalize it into a uniform glow with no markedly brighter central portion. When haze thinly overspreads the sky, its presence can only be detected by constant careful watching.

August 5th — Lat. 15° N.; Long. 161½° W.

10 P. M. to midnight, the sky was clear, but the western branch of the Light too low for good observations. The Gegenschein was distinctly visible as an oval at right angles to the ecliptic situated around *ι, τ, 29 Capricorni*, and to the N. and S. of this center extending nearly to *ν Aquarii, θ Capricorni, ε Capricorni*. At times it also seemed to include *ε, κ, δ Capricorni*, extending nearly to *λ Capricorni*, thus seeming circular, but with a *vacant* center, no light being visible between *τ* and *γ Capricorni*. It also had faint connecting bands running E. and W. about 4° broad. . . .

August 10th — Lat. 9½° S.; Long. 175° W.

. . . The Gegenschein visible from 8 P. M.; circular, with blank central space as before, but the whole was brighter than of late, and the blank space showed the slightest luminosity (though still darker than the surrounding portions) when overhead at 11 P. M.

The eastern branch was quite distinct at 10 P. M. (the night being magnificently clear); broad, too, and more southerly than of late. It consisted of a bright central portion about 10° broad, inclosed by diffused light. The Gegenschein was part of this bright central portion, surrounded, especially to the southward, by diffused light. The blank central space of the Gegenschein appeared the darkest spot in the Zodiacal Band as the eye traced it from the eastern horizon to the Galaxy. . . .

November 15th—Lat. 11° S.; Long. 169° E.

The Light was very distinct between 4 and 5 A. M., when the sky cleared. Its intensity equaled 6 to 7 in *Gemini*, *Leo*, and *Virgo*, evidently much as would be expected, lying along the usual line of central axis, 22° to 12° broad; so gave all my attention looking out for the *Leonids*. (Another *Leonid* observer asked me the next day, what the "curious white rainbow" was which he had noticed!)

1900. April 26th—Lat. 19¾° S.; Long. 161½° E.

. . . Between 2 and 2:45 A. M. the sky became very clear, and the eastern Light continually increased in altitude, breadth, and intensity (= 3 to 6). The Gegenschein became larger and brighter, circling round *89*, *85*, *86*, *94 Virginis*, continuing round 3° E. of λ and 3° S. of α to *89 Virginis*, its center being about 3° S. W. of λ *Virginis*. The western Light also became distinct (intensity = 3), broader, and cone-shaped, continuing till Moon rose at 2:45 A. M.

Remarks on the Light in April, 1900.

During the evening the Galaxy and *Venus* have sadly spoiled observations; but it has seemed as if there were hardly any brighter western cone — the Light appeared uniformly diffused, gradually becoming too faint for observation. However, into *Cancer* it could be traced with a fair amount of certainty, but in *Leo* its outlines have been very uncertain and unreliable, especially the northern. In *Virgo* and *Libra* again, outlines have been more reliable, especially soon after midnight.

The Gegenschein appeared fainter as the month progressed. Each night as the twilight glow subsided, a bright glow extended from near *Orion's* head into *Cetus* on the horizon.

The eastern Light invariably first appeared widely diffused, then gradually the central portion became brighter and formed a bright narrow cone, with apex between γ and η *Capricorni*, though as the steamer came south, the diffused Light on the southern edge of the cone was frequently visible when the northern diffused Light had quite disappeared.

May 23d—Lat. 29° S.; Long. 153½° E. (off Queensland Coast).
Moon's age, 24 days.

Air very clear; all stars very bright and clear. Galaxy = intensity 10.

6:30 P. M.—Galaxy and Zodiacal Light distinctly separated from *Gemini* at the western horizon. Light = Galaxy = 10, in *Gemini* and *Cancer*. Clouds intervene.

7:30 P. M.— Light visible around the sky to *Scorpio*, 10° above eastern horizon. Intensity = 5 in *Gemini* and *Cancer;* 4 in *Leo;* 3 in *Virgo* and *Libra*. *Venus* setting.

8:00 P. M.—Light brighter = Galaxy = 8 in *Gemini*, *Cancer*, and *Leo;* 6 in *Leo* and *Virgo;* 3 to 2 in *Libra*.

During this time in *Leo*, *Cancer*, and *Gemini*, the line of central axis appeared much displaced to the southward. The brighter portion ran along a line *Præsepe*, *Regulus*, *Spica* about 6° broad;

to the northward of this brighter portion there was no diffused light, whereas diffused light extended 10° to 8° along its southern outline. Hence the southerly displacement of the central axis.

Jnly 4th—Lat. 33½° N.; Long. 147° W. Moon's age, 7 days.

Misty night, with frequent breaks of intensely clear sky. Could distinguish twelve stars in the *Pleiades* with the naked eye. (o *Ccti* appears to be as bright as γ *Ceti.*) Galaxy = intensity 9 in *Scorpio*, fading to 0 in *Perseus* and *Taurus*. Zodiacal Light just discernible from 2:00 A. M. At 3:00 A. M. the Light = intensity 6 in *Aries* and *Pisces*. Light extended from *Pleiades* (cloudy below this point) to a few degrees beyond δ *Piscium*, the southern outline being best defined. Very hard to distinguish northern outline N. of *Pleiades* from twilight. No trace of Light in *Aquarius*.

A glow, roughly contained between *t*, ν, λ, ζ *Sagittarii*, may be the Gegenschein or may be due to the Galaxy.

R. M. S. "WARRIMOO," July 6, 1900.

PLANETARY PHENOMENA FOR SEPTEMBER, OCTOBER, NOVEMBER, AND DECEMBER, 1900.

By MALCOLM MCNEILL.

SEPTEMBER.

The Sun reaches the autumnal equinox September 23d, 4 A. M., P. S. T.

Mercury rises about an hour before the Sun on September 1st, but rapidly approaches superior conjunction, reaching it on September 13th, and becoming an evening star, but does not get far enough away for visibility during the rest of the month.

Venus is a morning star, and rises about three and one half hours before sunrise. It reaches its greatest western elongation, 46°, on the night of September 16-17th. It moves about 30° eastward and 4° southward from *Gemini*, south of *Castor and Pollux*, through *Cancer* into *Leo*, and at the end of the month is about 6° west and north of *Regulus*.

Mars rises before 1 A.M. It moves about 18° eastward and 3° southward from *Gemini* into *Cancer*. During the early part of the month it is in the neighborhood of *Castor and Pollux*, and on September 6th passes 6° south of *Pollux*. It is beginning to draw nearer the Earth, and while still not very conspicuous, it is nearly twice as bright as it was during conjunction in January.

Jupiter is drawing rather close to the Sun, and by the end of the month sets less than three hours after sunset. It is still in the constellation *Scorpio*, and moves about 4° eastward during the month.

Saturn is also in the western sky in the evening, somewhat higher up than *Jupiter*, and remains above the horizon until about 10 P. M. on September 30th. It ceases its westward motion and resumes its eastward motion on September 2d, and by the end of the month it has moved rather less than 1° along a line a little south of the course it pursued while moving westward.

Uranus moves a little less than 1° eastward in the constellation *Scorpio*, not far away from *Jupiter*. *Jupiter's* greater relative motion eastward is bringing the two planets nearer together, and at the end of the month *Uranus* is 2° east and 1° south of *Jupiter*. The planets are, however, so low down after sunset when the stars come out that it will not be an easy matter to see *Uranus* without a telescope.

Neptune is in about the same place on the dividing-line between *Taurus* and *Gemini*.

OCTOBER.

Mercury is an evening star throughout the month, coming to greatest east elongation on October 29th; but on account of the great southern declination of the planet, it remains above the horizon too brief a time after sunset to be visible, except possibly during the last few days of the month when the interval is about an hour.

Venus is a morning star, rising about three and one half hours before sunrise. It has begun to approach the Sun and the distance lessens about 4° during the month. Its motion among the stars is 32° eastward and 11° southward through *Leo* into *Virgo*. On October 7th it passes less than 1° south of *Regulus*, *α Leonis*.

Mars rises before midnight at the end of the month. It moves 17° eastward and 4° southward from *Cancer* into *Leo*, passing very close to the " Beehive " cluster in the former constellation during the first week of the month.

Jupiter is drawing too close to the Sun for the best observation, and by the end of the month sets less than two hours later. It moves about 6° eastward and southward during the month in *Scorpio*. There will be a very close conjunction with the Moon on the evening of October 26th, which will be an occultation west and south of the United States.

Saturn is in the southwestern sky in the evening, following about an hour after *Jupiter*. It is still in *Sagittarius*, north of the principal stars, and moves 2° eastward during the month.

Uranus is too low down after sunset for good observation. It is very near *Jupiter*, and the two planets are in conjunction on October 19th, *Jupiter* being 25′ north of *Uranus*. On October 26th *Uranus* is occulted by the Moon, the phenomenon taking place shortly after sunset in the eastern part of the United States.

Neptune is nearly stationary.

NOVEMBER.

Eclipse.—There will be an annular eclipse of the Sun on the morning of November 22d, visible only in the southern hemisphere. The path of the annulus begins in the South Atlantic, crosses South Africa and the Indian Ocean, and ends in Australia.

Mercury is an evening star at the beginning of the month, setting a little less than an hour after sunset, then rapidly approaches the Sun, passing inferior conjunction on November 20th, and becoming a morning star. By the end of the month it rises an hour and a half before sunrise, and will be an easy object to see in good weather.

Venus is a morning star, and is drawing nearer the Sun. The interval between its rising and sunrise shortens to about three hours at the end of the month from half an hour greater at the beginning. It moves 33° eastward and 13° southward from one end to the other of *Virgo*. On November 6th it passes 13′ north of the fourth-magnitude star η *Virginis*.

Mars rises earlier, at about 11 P.M., at the close of the month. It moves 13° eastward and 4° southward through the western part of *Leo*, and on November 18th passes about 1° 30′ north of *Regulus*, α *Leonis*.

Jupiter is drawing too close to the Sun to be conspicuously seen during the latter half of the month, the interval between sunset and its setting being less than an hour at the end. Still it is so bright that it can be seen if one looks sharply.

Saturn is also drawing nearer the Sun, and by the end of the month sets less than two hours after sunset. It moves 3° eastward in the constellation *Sagittarius* a little north of the handle of the "dipper."

Uranus is also in the neighborhood of the Sun, not quite as far to the east as *Jupiter*, and too near to be seen, on account of its faintness.

Neptune is retrograding (moving westward) slowly in the extreme eastern part of *Taurus*.

DECEMBER.

The Sun reaches the solstice, and winter begins December 21st, 10 P.M., P. S. T.

Mercury is a morning star throughout the month, and comes to greatest west elongation on the evening of December 7th. It then rises about an hour and three quarters before sunrise, and until nearly the close of the month the interval is more than an hour. So this is one of the best times of the year for seeing the planet if one is an early riser.

Venus is still a morning star, slowly overtaking the Sun on its eastward journey. The interval between the rising of the planet and the Sun shortens from three to a little more than two hours during the month. The planet moves 38° eastward and 10° southward from the eastern part of *Virgo* through *Libra* into *Scorpio*.

Mars is getting into position for evening observation, rising before 10 P. M. at the end of the month. It is still moving eastward among the stars in *Leo*, and traverses an arc of 8°, but the motion is slowing up, preparatory to the retrograde motion about the time of opposition in 1901. On December 16th it passes only 6′ south of the fifth magnitude star ι *Leonis*. Its actual distance from the Earth is diminishing, and on December 24th it is the same as the Earth's mean distance from the Sun. Its brightness has also increased, and at the end of December it is about six times as great as it was at the time of conjunction with the Sun in January. It will be much brighter than this at opposition, but is now beginning to be a noteworthy object.

The next three planets all come to conjunction with the Sun during December—*Jupiter* on the 14th, *Saturn* on the 29th, and *Uranus* on the 5th. Consequently, none of them are in good position for observation, and they will not be far enough away to be conspicuously seen as morning objects until February or March, 1901. There will be an interesting conjunction of *Mercury* and *Jupiter* on the morning of December 30th, *Mercury* being 44′ south of *Jupiter*. The latter can probably be seen in the morning twilight, but it is doubtful whether the former can be seen without a telescope.

Neptune is in opposition with the Sun on December 19th.

SEPTEMBER–OCTOBER, 1900.

PHASES OF THE MOON, P. S. T.

First Quarter . . .	Sept.	1,	11^h 56^m	P. M.
Full Moon	Sept.	8,	9 6	P. M.
Last Quarter . . .	Sept.	15,	12 57	P. M.
New Moon	Sept.	23,	11 57	A. M.
First Quarter . . .	Oct.	1,	1 11	P. M.
Full Moon	Oct.	8,	5 18	A. M.
Last Quarter . . .	Oct.	15,	1 51	A. M.
New Moon	Oct.	23,	5 27	A. M.
First Quarter . . .	Oct.	31,	12 17	A. M.

THE SUN.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
Sept. 1,	10^h 41^m	+ $8°$ $22'$	5^h 31^m A.M.	noon	6^h 29^m P.M.
11,	11 17	+ 4 39	5 42	11 57 A.M.	6 12
21,	11 53	+ 0 47	5 51	11 53	5 55
Oct. 1,	12 29	− 3 7	6 0	11 50	5 40
11,	13 5	− 6 57	6 11	11 47	5 23
21,	13 43	− 10 38	6 21	11 45	5 9
31,	14 21	− 14 3	6 32	11 44	4 56

MERCURY.

Sept. 1,	9 59	+ 13 56	4 31 A.M.	11 19 A.M.	6 7 P.M.
11,	11 12	+ 6 59	5 28	11 52	6 16
21,	12 18	− 0 53	6 21	12 18 P.M.	6 15
Oct. 1,	13 17	− 8 20	7 6	12 38	6 10
11,	14 13	− 14 49	7 46	12 55	6 4
21,	15 7	− 19 58	8 20	1 9	5 58
31,	15 54	− 23 13	8 40	1 16	5 52

VENUS.

Sept. 1,	7 39	+ 17 40	1 58 A.M.	8 59 A.M.	4 0 P.M.
11,	8 16	+ 16 59	1 57	8 56	3 55
21,	8 56	+ 15 33	2 2	8 56	3 50
Oct. 1,	9 38	+ 13 20	2 13	8 59	3 45
11,	10 21	+ 10 23	2 26	9 2	3 38
21,	11 4	+ 6 50	2 43	9 6	3 29
31,	11 47	+ 2 48	3 1	9 10	3 19

MARS.

Sept. 1,	7 3	+ 23 15	1 0 A.M.	8 23 A.M.	3 48 P.M.
11,	7 30	+ 22 35	12 49	8 10	3 31
21,	7 56	+ 21 41	12 40	7 57	3 14
Oct. 1,	8 21	+ 20 35	12 30	7 43	2 56
11,	8 45	+ 19 20	12 19	7 27	2 35
21,	9 8	+ 17 59	12 7	7 10	2 13
31,	9 29	+ 16 35	11 54 P.M.	6 52	1 50

JUPITER.

Sept. 1,	16 3	− 20 10	12 34 P.M	5 22 P.M.	10 10 P.M.
Oct. 1,	16 20	− 20 58	10 55 A.M.	3 40	8 25
Nov. 1,	16 44	− 21 54	9 22	2 3	6 44

SATURN.

Sept. 1,	17 53	− 22 36	2 32 P.M.	7 11 P.M.	11 50 P.M.
Oct. 1,	17 56	− 22 41	12 38	5 16	9 54
Nov. 1,	18 5	− 22 45	10 45 A.M.	3 23	8 1

URANUS.

Sept. 1,	16 27	− 21 43	1 4 P.M.	5 46 P.M.	10 28 P.M.
Oct. 1,	16 30	− 21 50	11 9 A.M.	3 51	8 33
Nov. 1,	16 37	− 22 3	9 14	1 55	6 36

NEPTUNE.

1900.	R. A.	Declination.	Rises.	Transits.	Sets.
Sept. 1,	$5^h 56^m$	+ 22° 14′	$11^h 55^m$ P.M.	$7^h 15^m$ A.M.	$2^h 35^m$ P.M.
Oct. 1,	5 57	+ 22 13	9 59	5 19	12 39
Nov. 1,	5 56	+ 22 12	7 56	3 16	10 36 A.M.

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

I, R,	Sept. 1,	$10^h 19^m$ P.M.	I, R,	Oct. 3,	$6^h 54^m$ P.M.
I, R,	3,	4 46	I, R,	19,	5 12
II, D,	3,	4 52	I, R,	26,	7 7
II, R,	3,	7 21	II, R,	30,	4 21
I, R,	10,	6 41			
II, D,	10,	7 30			
II, R,	10,	10 0			
I, R,	17,	8 35			
III, R,	23,	4 50			
I, R,	26,	5 0			
II, R,	28,	4 34			
III, D,	30,	6 44			

November–December, 1900.

Phases of the Moon, P. S. T.

Full Moon	Nov.	6,	$3^h\ 0^m$ P. M.
Last Quarter	Nov.	13,	6 37 P. M.
New Moon	Nov.	21,	11 17 P. M.
First Quarter	Nov.	29,	9 35 A. M.
Full Moon	Dec.	6,	2 38 A. M.
Last Quarter	Dec.	13,	2 42 P. M.
New Moon	Dec.	21,	4 1 P. M.
First Quarter	Dec.	28,	5 48 P. M.

The Sun.

1900.		R. A.	Declination.	Rises.	Transits.	Sets.
Nov.	1,	$14^h\ 25^m$	$-14^\circ\ 23'$	$6^h\ 34^m$ A.M.	$11^h\ 44^m$ A.M.	$4^h\ 54^m$ P.M.
	11,	15 5	−17 23	6 45	11 44	4 43
	21,	15 46	−19 53	6 57	11 46	4 35
Dec.	1,	16 29	−21 47	7 5	11 49	4 29
	11,	17 12	−23 0	7 16	11 53	4 30
	21,	17 57	−23 27	7 23	11 58	4 33
	31,	18 41	−23 7	7 26	12 3	4 40

Mercury.

Nov.	1,	15 57	−23 24	8 41 A.M.	1 16 P.M.	5 51 P.M.
	11,	16 15	−23 21	8 18	12 54	5 29
	21,	15 37	−18 29	6 42	11 37 A.M.	4 32
Dec.	1,	15 14	−15 18	5 28	10 35	3 42
	11,	15 47	−17 56	5 31	10 28	3 25
	21,	16 43	−21 33.	6 1	10 44	3 27
	31,	17 47	−23 55	6 37	11 00	3 41

Venus.

Nov.	1,	11 52	+ 2 22	3 3 A.M.	9 11 A.M.	3 19 P.M.
	11,	12 36	− 1 59	3 22	9 15	3 8
	21,	13 21	− 6 25	3 42	9 20	2 58
Dec.	1,	14 6	−10 43	4 4	9 27	2 50
	11,	14 54	−14 41	4 26	9 35	2 44
	21,	15 43	−18 5	4 48	9 45	2 42
	31,	16 35	−20 42	5 11	9 57	2 43

Mars.

Nov.	1,	9 31	+16 26	11 53 P.M.	6 50 A.M.	1 47 P.M.
	11,	9 50	+15 2	11 38	6 30	1 22
	21,	10 8	+13 41	11 22	6 9	12 56
Dec.	1,	10 24	+12 28	11 2	5 45	12 28
	11,	10 38	+11 25	10 41	5 20	11 59 A.M.
	21,	10 49	+10 38	10 16	4 52	11 28
	21,	10 57	+10 11	9 45	4 20	10 55

JUPITER.

Nov. 1,	16 44	— 21 54	9 22 A.M.	2 3 P.M.	6 44 P.M.
Dec. 1,	17 12	— 22 39	7 54	12 33	5 12
Jan. 1,	17 43	— 23 5	6 24	11 1 A.M.	3 38

SATURN.

Nov. 1,	18 5	— 22 45	10 45 A.M.	3 23 P.M.	8 1 P.M.
Dec. 1,	18 18	— 22 45	9 0	1 38	6 16
Jan. 1,	18 34	— 22 37	7 14	11 52 A.M.	4 30

URANUS.

Nov. 1,	16 37	— 22 3	9 14 A.M.	1 55 P.M.	6 36 P.M.
Dec. 1,	16 44	— 22 17	7 24	12 4	4 44
Jan. 1,	16 52	— 22 31	5 32	10 11 A.M.	2 50

NEPTUNE.

Nov. 1,	5 56	+ 22 12	7 56 P.M.	3 16 A.M.	10 36 A.M.
Dec. 1,	5 53	+ 22 11	5 51	1 11	8 31
Jan. 1,	5 49	+ 22 11	3 46	11 6 P.M.	6 26

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off right-hand limb as seen in an inverting telescope.)

I, R, Nov.	4,	3^h 30^m P.M.	III, R, Nov.	5,	4^h 51^m P.M.
III, D,	5,	2 38 P.M.	I, R,	11,	5 25 P.M.

No eclipses visible this year after November 11th, *Jupiter* being too near the Sun.

NOTICES FROM THE LICK OBSERVATORY.[*]

PREPARED BY MEMBERS OF THE STAFF.

It has seemed appropriate to supplement the account of the life-work of Professor **KEELER**, which Professor **CAMPBELL** has written for the Society, with a more extended account of the scientific investigations which claimed his attention during the two years of his Directorship of the Lick Observatory, especially as we have such an account from his own pen — the last article written by him. We therefore reprint in this number the article on "The Crossley Reflector of the Lick Observatory," which Professor **KEELER** contributed to the June (1900) number of the *Astrophysical Journal.*

VENUS BY DAYLIGHT.

In his notes on Planetary Phenomena in No. 73 of these *Publications*, Professor **MCNEILL** called attention to the fact that *Venus* could readily be seen in full daylight in clear weather throughout the month of May of this year. It may be of interest to note that the planet was seen here without difficulty whenever it was looked for by daylight in the months of March, April, and June, as well as May.

Venus came to inferior conjunction with the Sun on July 7th, and I was interested to see how near this date it could be seen by daylight without telescopic aid. On June 29th, at 3 P.M., I found it clearly visible to the naked eye without the aid of a "pointer." On July 2d, at 12:30 P.M., it was seen with the greatest difficulty, and only by using the telescope tube as a "pointer." On July 5th, at 10:30 A.M., the 12-inch telescope was turned on the planet, the object-glass being screened as far as possible from direct sunlight. *Venus* appeared as an exceedingly narrow crescent that could be traced through fully 180°. At its widest part, the width of the crescent was estimated at less than one second of arc. After passing the Sun, the planet was not looked for by daylight until August 22d, at 10 A.M., when it was, of course, very easily seen. R. G. AITKEN.

---

[*] Lick Astronomical Department of the University of California.

DISCOVERY OF THREE HUNDRED DOUBLE STARS.

During the years 1898–99, I was engaged in remeasuring all the double stars discovered at Pulkowa, principally from 1841 to 1843, by OTTO STRUVE. In the course of this work I discovered new companions to a few of these stars. I also frequently measured other pairs which happened to be in the vicinity of those found by OTTO STRUVE, and some of these miscellaneous pairs have proved to be new.

When the work on the Pulkowa stars drew towards a close, so that considerable gaps existed in my programme, I began to examine large numbers of stars in various parts of the sky, particularly towards the south, in the hope of discovering new pairs. This work has now been carried on systematically for about fourteen months, resulting in the discovery of three hundred new double stars, having distances under five seconds of arc.

Sets of measures of these stars have been obtained as speedily as circumstances have permitted. Observations of one hundred pairs were printed in the *Astronomical Journal*, No. 480, and observations of a second hundred have been forwarded to the same periodical for publication. Sets of measures of the third hundred have not yet been completed, though most of them have been observed on at least one night.

With respect to the distances between their components, these new pairs have the following classification:

0″.25 or less,	18 pairs.
0 .26 to 0″.50,	41 "
0 .51 to 1 .00,	63 "
1 .01 to 2 .00,	80 "
2 .01 to 5 .00,	98 "
	300

Many of these stars are difficult to measure, either on account of the closeness of their components or the faintness of their companions. On this account I have generally observed them with the 36-inch telescope. Some of the close pairs, even some of those whose distances do not exceed 0″.25, have been discovered with the 12-inch telescope. But measures of such pairs have not been made with this instrument.

It would have been an easy matter to have increased the number of discoveries considerably by including pairs having distances somewhat greater than 5″. This, however, has not seemed desirable, and only a few such pairs have been measured, and the results for one only published. W. J. HUSSEY.

September 18, 1900.

ELLIPTIC ELEMENTS OF COMET 1896 V, GIACOBINI.

In November, 1896, I computed elements of the orbit of this comet from places corresponding to the dates 1896, September 8th, October 5th and 29th. The elements then obtained did not accurately represent the observed path of the comet during the latter part of its apparition. About a year ago I found the origin of the discrepancy in a slightly erroneous position of the comparison-star used for the last observation, and at that time computed the system of elements given below. These elements are based on normal places having the dates 1896, September 8th, October 29th, and 1897, January 4th. The interval included between the extreme dates is only four days less than the apparition period of the comet.

Epoch 1896 November 1.5 G. M. T.

$$\begin{array}{rrrr} M = & 0^\circ & 39' & 56''.5 \end{array}$$

$$\left.\begin{array}{rrrr} \Omega = & 193 & 28 & 47.4 \\ i = & 11 & 21 & 14.7 \\ \omega = & 140 & 33 & 43.4 \end{array}\right\} 1896.0$$

$$\begin{array}{rrrr} \phi = & 35 & 42 & 7.6 \end{array}$$

$\log e = 9.766094$

$\log a = 0.542898$

$\mu = 544''.0765$

Period = 6.52 years. W. J. HUSSEY.

PROPER MOTION OF OΣ *165*, *45 GEMINORUM*.

OTTO STRUVE discovered a faint companion of *45 Geminorum* about 1842, and first measured its position in 1847. Misled by erroneous observations made in 1877, he thought that the change in the relative positions of the two stars was due to orbital motion. This, however, is not the case. It results entirely from the proper motion of the principal star. This is clearly established by comparing the proper motion of the principal star as derived from the micrometrical measures with that furnished by the meridian observations. I have obtained the following results from the measures of position-angle and distance:—

$$\mu = -\,0^{s}.00046, \qquad \mu' = -\,0''.1058,$$

while those given by Professor NEWCOMB in his "Catalogue of Fundamental Stars," derived from the meridian observations of the principal star, are:—

$$\mu = -\,0^{s}.00075, \qquad \mu' = -\,0''.1090.$$

These results are in substantial agreement; their differences may be attributed entirely to errors of observation.

W. J. HUSSEY.

VISUAL EXAMINATION OF *CAPELLA*.

[Reprinted from *Astronomical Journal*, No. —.]

Some months ago Professor CAMPBELL discovered that *Capella* is a spectroscopic binary having a period of 104 days. From the spectroscopic observations it is known that the orbit is nearly circular, and that the components are not very unequal in brightness. The variations of the velocities of the components in the line of sight furnish the minimum dimensions of the orbit. A combination of these dimensions with ELKIN'S parallax gives a result from which it appeared not impossible that *Capella* might at times be seen as a visual double star, thus forming a connecting link between the visual and spectroscopic binaries. The recent most favorable dates for the examination of the star to this end were April 15th, June 6th, and July 28th. At these times the apparent distance between the components would be a maximum. On account of the orbit's being nearly circular the apparent distance has nearly its maximum value for a few days on either side of the dates given.

Early in June I examined *Capella* on several afternoons with the 36-inch telescope without obtaining any visual evidence of its being a double star. The results then obtained, however, were not regarded as conclusive; for the seeing, though good, was not such as to be rated as excellent according to our standards. These examinations were made when the star was from three to four hours west of the meridian.

On the nights of August 2d and 5th I made further examinations with the same telescope, using powers 1000, 1500, 1900, and 2600. With all powers the star appeared round. On these dates the seeing was excellent and stood all these powers perfectly. On the last date the seeing was perhaps the best. Even at Mt. Hamilton we have few nights that are better in the course of a year. With such conditions as then prevailed an elongation of a tenth of a second would have been readily perceptible with the lowest power used, and a considerably smaller distance would have been noted with the higher ones. At the times of these observations the star was between three and four hours east of the meridian. On August 5th color-screens of various shades were used a part of the time to reduce the light. On this date Mr. PERRINE was with me. He also made a very careful examination of the star with all powers, without detecting any elongation.

W. J. HUSSEY.

MT. HAMILTON, Aug. 10, 1900.

NOTE ON *CAPELLA* AS A DOUBLE STAR.

The elements deduced from the spectroscopic observations of this binary system indicated the possibility that the two components might be sufficiently separated to be seen directly with the 36-inch refractor. The star was therefore examined with that instrument under good conditions on the evenings of February 24th, and April 16th, and on the mornings of July 22d, July 29th, and August 11th. Once or twice, especially on the first night, a slight elongation was suspected, but settings with the micrometer ranged over 60°, showing that no real elongation was observed. On the morning of July 29th, the seeing was very good; several very difficult stars were measured shortly before turning to *Capella;* and the latter star was followed for over an hour, using eye-pieces of all powers to 2600, with and without shades of red and orange glass, but no certain elongation could be detected. The spectroscopic observations show that the separation of the two components was a maximum on the dates February 22d, April 15th, and July 28–29th.

R. G. AITKEN.

September, 1900.

THE TRIPLE STAR *κ PEGASI.*

The visual double star having the shortest known period of revolution is the fourth-magnitude star *κ Pegasi*. It was discovered by BURNHAM in 1880 with the 18½-inch telescope, and is one of the very difficult stars on his list. The approximate magnitudes of the two components are 4½ and 5. The major semi-axis of the relative elliptic orbit of one around the other is 0".4, and the period of revolution is a little over eleven years. The present distance between the components is less than 0".2, in position-angle 260°.

One of the components — probably the component whose spectrum is the stronger in the blue region — is a spectroscopic binary. *κ Pegasi* is therefore a triple star of more than usual interest. The shifting of the lines in the spectrum, as observed with the Mills spectrograph, have furnished the following velocities of one component, with reference to the solar system:

DATES.	VELOCITY.
1896, Aug. 31	-43^{km}
1899, July 17	-41
1900, Aug. 6	$+35$
" 7	$+27$
" 8	-16
" 12	$+35$
" 21	-45
" 22	-34

The variation in the velocity was discovered from the third plate. The period of rotation of the bright component around an invisible companion is about six days.

Changes in the appearance of the spectrum have been noted, but I have not yet determined their nature.

On account of the closeness of the two visual components, it is impossible to secure their spectra separately; and for this reason I am not able to state which visual component is the spectroscopic binary. W. W. CAMPBELL.

A NEW PLANETARY NEBULA.

While examining Comet *b* 1900 (BORRELLY-BROOKS) with the 12-inch telescope on the evening of August 31st, I found D.M. +83° 357 (9.4^{m}) to be a small nebula instead of a star. An examination with the 36-inch telescope on the following night showed that the object was a nebulous star or very small planetary nebula. The nucleus is stellar, of about 10½ to 11 magnitude, and is centrally placed in a round nebulous envelope which is between 5" and 6" in diameter. The nebula as a whole is about as bright as a 9.5 magnitude star. A 13-magnitude star precedes 14.8" in 263°. The position of the nebula for 1855.0 is $12^{h}\ 29^{m}\ 10^{s}$, +83° 21.8" (B. B. VI.). R. G. AITKEN.

COMET *b*, 1900 (BORRELLY-BROOKS).

This comet was discovered by **BORRELLY** at Marseilles on the 23d of July, and independently the same night by **BROOKS** at Geneva, N. Y. It was observed here on the 24th, when it appeared as a very beautiful object. At that time the nucleus gave evidence of being double, and was of the 6½ magnitude. The following night the nucleus and whole head appeared perceptibly fainter. The nucleus no longer appeared double, but was elongated in the direction of the axis of the tail. Mr. **PALMER** photographed this comet on the night of the 25th. An exposure of one hour and a half shows a little over six degrees of tail. Two photographs taken the next night, one by Mr. **PALMER**, the other by myself, show only about one degree of tail. These exposures were for two hours.

According to elements by Mr. **PERRINE**, the comet passed perihelion on the 3d of August. An observation was made on the 11th of August, at which time the nucleus was sharp, round, and of the 11th magnitude, the magnitude of the whole head being 9½.

R. T. CRAWFORD.

ELEMENTS OF COMET *b*, 1900 (BORRELLY-BROOKS).

From Mr. **CRAWFORD**'s observation of July 25th, and my own of July 30th and August 4th, I find the following parabolic elements:—

$$T = 1900 \text{ August } 3.20726 \text{ G. M. T.}$$

$$\left.\begin{array}{rrrr} \omega = & 12^\circ & 26' & 13''.2 \\ \Omega = & 328 & 0 & 30\ .1 \\ i = & 62 & 30 & 46\ .3 \end{array}\right\} 1900.0$$

$$\log q = 0.006390$$

Residuals: Observed - Computed.

$\Delta \lambda' \cos \beta' \qquad +4''.4$

$\Delta \beta' \qquad -0\ .9$

C. D. PERRINE.

MT. HAMILTON, Cal., Sept. 13, 1900.

HONOR FOR PROFESSOR CAMPBELL.

At the annual commencement on June 14, 1900, the Western University of Pennsylvania conferred the degree of Doctor of Science upon Professor W. W. **CAMPBELL**, senior astronomer in the Lick Observatory.

ASTRONOMICAL TELEGRAMS.

(Translations.)

CAMBRIDGE, MASS., July 10, 1900.
To Professor JAMES E. KEELER, (Received 4:30 P.M.)
Lick Observatory.

A new star has been found by Mrs. FLEMING. Position for 1900.0, $19^h\ 15^m\ 16^s$, Decl. $-0°\ 19'$. In April, 1899, it was of the 8th magnitude, now it is a nebula of the 12th magnitude. We have 16 photographs. (Signed) E. C. PICKERING.

To Lick Observatory, BOSTON, MASS., July 24, 1900.
Mt. Hamilton, Cal. (Received 7:15 P.M.)

A bright comet was found by Dr. W. R. BROOKS [Geneva, N. Y.,] on July 23.750, Greenwich, M. T., in R. A., $2^h\ 43^m.6$, Decl. $+12°\ 30'$. Its motion is northerly. It has a nucleus and a tail. (Signed) JOHN RITCHIE.

CAMBRIDGE, MASS., July 24, 1900.
(Received 7:15 P.M.)

Kiel cables for Lick Observatory the following ephemeris of the periodic Comet De Vico-Swift, computed by F. H. SEARES.[*] Please look for the comet, and telegraph any observations.
(Signed) E. C. PICKERING.

Lick Observatory, August 8, 1900.
To Harvard College Observatory: (Sent 9:20 A.M.)

The following elements and ephemeris[†] of Comet *b* 1900 (BORRELLY-BROOKS) were computed by C. D. PERRINE from observations of July 25th, 30th, and August 4th:—

$$T = \text{G. M. T. August } 3.21.$$

$$\left.\begin{array}{l} \omega = \ \ 12°\ 26' \\ \Omega = 328\ \ \ \ 1 \\ \iota = \ \ 62\ \ \ 31 \end{array}\right\}$$

$$\text{Natural } q = 1.0148.$$

(Signed) JAMES E. KEELER,
Per W. W. CAMPBELL.

RESIGNATION OF MR. CODDINGTON AS FELLOW AT THE LICK OBSERVATORY.

Mr. E. F. CODDINGTON, Fellow in Astronomy at the Lick Observatory during the years 1897–1900, resigned his Fellow-ship in June, to take effect August 1st. It is Mr. CODDINGTON'S purpose to devote one or two years to the further study of theoretical astronomy and related subjects, in some of the European universities.

---

[*] The ephemeris for four-day intervals, from July 23d to August 4th, is here omitted.

[†] The ephemeris at four-day intervals, from August 10th to August 22d, is here omitted

It is a pleasure to say that Mr. CODDINGTON'S services to the Lick Observatory during his three years' residence are highly appreciated by every member of the staff, and that he carried with him our best wishes for his future career. W. W. C.

APPOINTMENT OF FELLOW AT THE LICK OBSERVATORY.

The Regents of the University of California have appointed Dr. HERBERT MEREDITH REESE to the position of Fellow in Astronomy at the Lick Observatory, for the year beginning October 1st. Dr. REESE is an alumnus of Johns Hopkins University, having received there the degrees A. B. in 1897 and Ph. D. in 1900. He held University Scholarships for three years, and last year was a Fellow in Physics.

During the past three years Dr. REESE has been engaged, in the Johns Hopkins Physical Laboratory, in an investigation of the "Zeeman Effect," with reference to the principal chemical elements; i. e. the effect of a magnetic field upon the character of the lines in the spectra of the elements.

Dr. REESE was an assistant to the U. S. Naval Observatory Expedition which observed the total solar eclipse of May 28, 1900, at Pinehurst, N. C. W. W. C.

APPOINTMENT OF ACTING DIRECTOR OF THE LICK OBSERVATORY.

The Regents of the University of California, at a meeting held on September 12th, appointed Astronomer W. W. CAMPBELL to the position of Acting Director of the Lick Observatory, to serve until such time as a new director is elected and assumes the duties of his office.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

The Grand Prize of the Paris Exposition has been awarded to Professor A. MICHELSON, of the University of Chicago, for his Echelon spectroscope.

The honorary degree of Doctor of Science was conferred upon Professor ARMIN O. LEUSCHNER, head of the Department of Astronomy at Berkeley, by the Western University of Pennsylvania at the last annual commencement — June 14, 1900.

The Queen Regent of Spain has signed a decree establishing the method of accounting time in the kingdom as follows:—

(1) In all railway, mail (including telegraph), telephone, and steamship service in the Peninsula and the Ballearic Islands, and in all the ministerial offices, the courts, and all public works, time shall be regulated by the time of the Greenwich Observatory, commonly known as western European time.

(2) The computation of the hours in the above-mentioned services will be made from the hour of midnight to the following midnight in hours from 1 to 24, omitting the words *tarde* (afternoon) and *noche* (night), heretofore in customary use.

(3) The hour of midnight will be designated as 24.

(4) The interval, for instance, between midnight (24) and 1 o'clock will be designated as 0.05, 0.10, 0.59. —*Science.*

Spain is thus the first nation in the world to adopt the astronomical, or 24-hour, method in the reckoning of civil time.

Observations of *Capella* as a double star have been made at Greenwich by no less than ten different observers. The observers state that "the change of position-angle observed through a large arc of the orbit agrees on the whole well with the calculated change, taking the period as 104 days." So far as we know, these results have not been confirmed by observations elsewhere.

Science (August 31, 1900) states that the degree of Doctor of Philosophy has been conferred this year on 233 candidates by twenty-two universities in the United States. In 1899 the number was 224, and in 1898, 234. Making a somewhat arbitrary distinction between the humanities and the sciences, there would seem to be very little difference in the numbers of students in the two classes; for the degree has been conferred in the sciences 105, 115, and 113 times; in the humanities 129, 109, 120 times.

The distribution of students among the different sciences shows that chemistry offers the greatest attraction, and meteorology the least, 85 degrees having been granted in the one, and 1 in the other in the three years.

Nine doctorates have been granted to candidates offering astronomy as their major. We give herewith the names of the four receiving the degree this year and the titles of their theses:

G. N. BAUER: The Parallax of μ *Cassiopeiæ* and the Positions of 56 Neighboring Stars as Determined from the Rutherford Photographic Measures. Columbia University.

CAROLINE E. FURNESS: Catalogue of Stars within One Degree of the North Pole, and Optical Distortion of the Helsingfors Astro-photographic Telescope, deduced from Photographic Measures. Columbia University.

F. R. MOULTON: A Particular Class of Periodic Solutions of the Problem of Three Bodies. University of Chicago.

H. N. RUSSELL: The General Perturbations of the Major Axis of *Eros* caused by the Action of *Mars;* with the Corresponding Terms in the Mean Longitude. Princeton University.

* * *

The second annual meeting of the Astronomical and Astrophysical Society of America was held on June 26–28, 1900, at Columbia University, in connection with the forty-ninth annual meeting of the American Association for the Advancement of Science.

The Secretary's report of the action of the Council showed an increase of forty-three in the membership of the Society during the year. Officers for the year 1900–01 were elected as follows: President, SIMON NEWCOMB; Vice-Presidents, C. A. YOUNG and G. E. HALE; Secretary, G. C. COMSTOCK; Treasurer, C. L. DOOLITTLE; Councillors, E. C. PICKERING, J. E. KEELER, ORMOND STONE and S. J. BROWN.

It was voted to hold the next meeting of the Society in Denver, Colo., in August, 1901.

About forty papers were read at the joint sessions of the Society with Section A of the A. A. A. S., and in addition the observations of the total solar eclipse of May 28, 1900, and the programme to be followed in observing *Eros* for parallax at the approaching opposition were discussed at length. A general account of these discussions with abstracts of the papers presented before the Society is given by the Secretary, Professor COMSTOCK, in *Science*, Nos. 291 and 292.

* * *

In addition to the general accounts of the two expeditions sent from California to observe the Total Eclipse of the Sun last May (which are printed elsewhere in this number), it should be said that nearly all the parties, both in this country and in Europe, were quite successful, especially in the photographic observations. The spectroscopic and spectrographic results are more disappointing, and a number of parties report complete failures in these respects.

Extensive preliminary reports from most of the American parties are printed in the *Astrophysical Journal* for July, 1900. Considerable interest attaches to the results obtained with the bolometer, by members of the Smithsonian Institution party. These are summarized by Professor C. G. ABBOT, in the following statements:—

"1. The coronal radiation was recognized by the bolometer, and gave at least 5^{mm} deflection over that of the dark Moon.

"2. The radiation reflected by the Earth's atmosphere during the partial phase is vastly more intense than that of the corona.

"3. *The corona is effectively cooler than the bolometer, and appears, therefore, neither to reflect much light from the Sun nor chiefly by virtue of a high temperature to give light of its own, but seems rather to be giving light in a manner not associated with a high temperature, or at least with the preponderance of infra-red rays usual in the spectra of hot bodies.*

"As the last statement," adds Dr. ABBOT, "involves a rejection of both the eruptive and meteoric coronal theories, it ought to receive searching criticism, and the experimental observations on which it rests ought to be verified at future eclipses."

* * *

Professor T. C. CHAMBERLIN and Dr. F. R. MOULTON have recently been attempting to test the Nebular Hypothesis as formulated by LAPLACE (1) by means of the modern kinetic theory of gases, (2) by a comparison of the moment of momentum of the supposed nebular system with the moment of momentum of the actual system, and (3) by a study of the ratios of masses to momenta. In *Science* (August 10, 1900), the authors give an interesting abstract of three of their recent technical papers. Without attempting to summarize their argument, we may state that their conclusion is altogether adverse to the tenability of the hypothesis. An original spheroidal nebulous or meteoroidal form of any kind is incompatible with the present distribution of the masses and momenta in the system. In any attempt to construct a tenable hypothesis, "the matter of the system must be so brought together as to give low mass, high momentum, and irregular distribution to the outer part, and high mass, low momentum, and sphericity to the central part." With reference to such an hypothesis, two suggestions are offered (both purely as conjectures) namely, that the system may have been originated by the peripheral collision of a very small nebula upon a large one; or that its primitive form may have been that of a spiral nebula.

Under the auspices of the International Astrophotographic Conference an extensive plan of campaign has been outlined for the determination of the solar parallax from observations of the minor planet *Eros* at its approaching opposition.

It will be remembered that *Eros* at certain oppositions approaches the Earth far more nearly than any other member of the solar system except the Moon, and that this year's opposition is more favorable than any other until the one of 1931. (See these *Publications*, No. 66, pp. 40–44.)

The Conference at its session in Paris, July 19–25, 1900, therefore adopted resolutions declaring it to be desirable that micrometric, heliometric, and photographic observations of *Eros* should be made for the purpose of determining the parallax constant, (*a*) by combining the morning and evening observations at the same observatory, (*b*) by combining the observations made at approximately the same absolute time in Europe and North America, and (*c*) by combining the (nearly) simultaneous observations made at northern and southern observatories. A great deal of work in addition to the actual parallax observations is necessary to insure the highest degree of accuracy. All the stars along the trajectory of the asteroid during the period of observation are to be photographed to afford means of determining with precision the places of the faint stars that must necessarily be used in the micrometer observations. To give reference points for measuring these plates, 319 of the brighter stars must be observed with the meridian circle at a number of observatories. To eliminate the uncertainty still existing in our knowledge of the motion of *Eros*, various precautions must be taken in combining the observations, and an independent series of observations, both micrometric and photographic, should be available for perfecting the theory of the motion. M. ANDRÉ and M. PROSPER HENRY will also undertake special researches upon the atmospheric dispersion.

As more than thirty different observatories have agreed to co-operate in this work, we may confidently expect a very accurate determination of this fundamental constant of astronomy.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, SEPTEMBER 22, 1900, AT 3:30 P.M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED SEPTEMBER 22, 1900.

Mr. J. W. BLESSING	Risingsun, Ohio.
Mr. RAY E. CHASE	Chico, Cal.
Mr. J. D. GALLOWAY	1426 Myrtle St., Oakland, Cal.
Mr. JOHN D. HOOKER	325 West Adams St., Los Angeles, Cal.
Mr. WM. H. KNIGHT	1012 West Eighth St., Los Angeles, Cal.
Mr. SAM L. WALLER	1217 Post St., S. F., Cal.
Mrs. FLEETWOOD WELLS	Kamloops, British Columbia.

The following resolutions were adopted by the written consent of the eleven Directors, namely: Messrs. KEELER, BURCKHALTER, TOWNLEY, CAMPBELL, PERRINE, HILL, PIERSON, DOLBEER, MOLERA, ZIEL, and Miss O'HALLORAN:—

Resolved, That the Treasurer be, and he hereby is authorized to withdraw from the Life Membership Fund such sums of money (not to exceed a total of $500), as may become necessary to defray the expenses of the General Fund, during the current fiscal year, provided that the amounts withdrawn be repaid to the Life Membership Fund with the first available money.

Resolved, That no award of the Bruce Medal be made for the year 1901.

The Secretary reported that no meetings were held at the Lick Observatory on September 1st, owing to the lack of a quorum.

Upon motion by Mr. PIERSON, the following resolution was adopted by the Board of Directors:—

Resolved, That in the death of JAMES EDWARD KEELER, this Society has sustained an irreparable loss, and each one of us a personal affliction. As charter member of the Society, as one of its Board of Directors and as its President, we learned through many years to admire his pure and lofty character, and to respect his profound ability in the Science to which he dedicated his manhood. A man of sweet, unsullied life, a patient, tireless worker in the problems of infinite space, a fond husband a tender father, a master of Science, he stood for all that was good and great and true.

The Secretary was instructed to forward a copy of these resolutions to Mrs. KEELER.

A committee appointed by First Vice-President BURCKHALTER, consisting of Messrs. LOWDEN, PARDEE and CUSHING presented the following resolutions on behalf of the members of the Astronomical Society of the Pacific:—

In Memoriam.

WHEREAS, Professor JAMES EDWARD KEELER, Director of the LICK OBSERVATORY at Mount Hamilton, and President of this Society, died on the twelfth day of August, 1900; and

WHEREAS, The Members of this Society regard this as an appropriate time to express their appreciation of the life and services to science of one who in life sought the praise of none; now therefore, be it

Resolved, That in Professor KEELER we recognize an American citizen of the best type, a man of broad culture, and high scientific attainments, whose reputation as a skilled astronomer was world-wide, and who, by his patient work and consummate ability, aided much in acquiring and maintaining a high standing in the scientific world for the many institutions with which he was connected during his active life.

Resolved, That while by the death of this distinguished scholar Astronomical Science has suffered a great loss, this Society in particular has been deprived of one who has been connected with it from its incorporation, and who, whether in the capacity of Member, Director, or President, has at all times accorded to this Society his unqualified support, and materially assisted in giving it a standing among like Societies throughout the world.

Resolved, In token of our appreciation of Professor KEELER'S efforts in behalf of this Society and of our love for him, that these resolutions be spread in full on our minutes, and that a copy thereof be sent with our heartfelt sympathy to the bereaved family.

SAN FRANCISCO, September 22, 1900.

ASTRONOMICAL SOCIETY OF THE PACIFIC.
WILLIAM H. LOWDEN,
CHARLES S. CUSHING,
GEORGE C. PARDEE,
Special Committee.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XII. SAN FRANCISCO, CALIFORNIA, DECEMBER 1, 1900. NO. 76.

TRIAL ELEMENTS OF THE ORBIT OF δ *EQUULEI*, OΣ 535.

BY WILLIAM J. HUSSEY.

The periodic time of this binary, according to the elements which I have obtained, is 5.7 years. This is only a little more than half of the period of *κ Pegasi*, whose time of revolution according to BURNHAM'S elements is 11.37 years, and which has hitherto been accepted[*] as the shortest known among the visual double stars.

My elements of δ *Equulei* are to be regarded as tentative — to be accepted if they represent the motion in the future, to be rejected if they fail in this respect. They have been obtained in the course of an investigation which has had for its object the explanation of the very rapid change in the relative positions of the components of this pair during the past fifteen months. In the summer of 1899 this star was measured with comparative ease with the great telescope. The distance was then fully three tenths of a second. Early in September, 1900, Professor AITKEN called my attention to the fact that it had become an exceedingly difficult pair. It is now too close for exact measurement. We have each examined it on a number of nights recently with the 36-inch telescope when the atmospheric conditions were favorable, and have found it either apparently round or so slightly elongated as to render the results of attempts to measure the direction of elongation very uncertain. According to the elements of its orbit heretofore published, the apparent distance should now be somewhat more than a quarter of a second. As a matter of fact, it is less than one tenth of a second.

---

[*] In 1897, SEE published elements of β 883, with a period of 5.5 years. In Volume I of the *Publications of the Yerkes Observatory*, Professor BURNHAM states that from a careful consideration of all the measures of this star, it is practically certain that the period of five and one half years is not correct, and that it is probable that the period will not be far from that of GLASENAPP, which is 16.35 years. LEWIS, using observations from 1879 to 1900, inclusive, obtains elements with a period of 15.8 years.

Professor AITKEN has followed this star very closely during the past five years, measuring it at short intervals to obtain as nearly as possible a continuous series of observations. His results indicate a much longer period than five and one half years.

This close pair was discovered and first measured by Otto Struve in 1852. Soon thereafter it was ascertained that its motion is rapid; but it was not until 1880 that sets of measures began to be obtained with that regularity and continuity which are necessary to furnish the data for a reliable determination of its orbit. From his own observations, Otto Struve thought the periodic time was either about thirteen years or half of this amount. He was inclined to accept the latter as the more probable.

After the publication of the sets of measures by Burnham for the years 1880 to 1883, inclusive, Wroublewsky made the first determination of the elements of the orbit, obtaining a period of 11.478 years. His results were published in 1887. In 1895, when the available data for such an investigation had increased considerably, See derived elements which in their essential features are practically the same as those obtained by Wroublewsky. These were slightly modified when reprinted the next year in his *Evolution of Stellar Systems*. Their results are as follows:—

	Wroublewsky.		See (1895).	See (1896.)
Period =	11.478 years.		11.45 years.	11.45 years.
$T =$	1892.03		1892.80	1892.80
$\Omega =$	24°.05	1870	22°.2	22°.2
$\lambda = \pi - \Omega =$	26 .61		0 .00	0 .0
$i =$	81 .75		79 .05	79 .0
$e =$	0 .2011		0 .14	0 .165
$a =$	0″.406		0″.452	0″.452

The components of δ *Equulei* do not differ much in brightness. In the years 1897, 1898, and 1899, I measured this star thirteen times. On two nights I thought the companion was in the third quadrant, on eight in the first quadrant, and on three I was in doubt. Whenever the atmospheric conditions are unfavorable, it is difficult to determine the quadrant of this pair with certainty. In this respect the published observations present numerous discordances, and in some instances observers appear to have been guided by Wroublewsky's elements in fixing the quadrant rather than by their own independent examinations. On account of these discrepancies, it is necessary to alter the position-angles of some of the observations by 180°, in order to arrange the data for a determination of the elements of the orbit.

When the observations are arranged to correspond to a period of nearly eleven and one half years and then plotted, nearly all the points representing them fall into one or the other of two groups, situated upon opposite sides of the origin, in approximately the directions 20° and 200°. On one side the observations are somewhat more numerous than on the other, and the extreme distances there are a little greater. When one attempts to draw an apparent ellipse guided by the consideration that the areas described by the apparent distance vary proportionally to the times of their description, it is found that the observations can be satisfied only by making the apparent ellipse such that the true orbit is nearly circular. It will be noticed that the eccentricity, as given by WROUBLEWSKY and by SEE, is very much smaller than is usually found in double-star orbits.

I computed a system of elements for δ *Equulei* in accordance with the hypothesis that the period is about eleven and one-half years, and at once obtained a smaller value for the eccentricity than those given above. With these provisional elements, I computed the mean anomalies corresponding to all the observed position-angles which appeared to be reliable, my judgment of their reliability being based upon the results obtained in the course of the measurement of the areas described by the apparent distance. When these mean anomalies were plotted, using the time as the independent variable, it was found that they deviated systematically from a straight line, along which they should lie in accordance with theory. Values corresponding to the observations which had been assumed to belong on one side of the origin were situated above the line that best represented them, taken as a whole, while those on the opposite side of the origin fell below it. I examined the effect which a variation of the several elements would have upon this systematic deviation and concluded that to remove it, it would be necessary further to decrease the eccentricity. By successive steps this was done until the eccentricity had become 0.05, or until the true orbit was assumed to be as nearly circular as that of *Jupiter*. Even then the mean anomalies did not conform to theoretical requirements, and it became apparent that this would not be the case unless the eccentricity was taken equal to zero, or the true orbit assumed to be a circle. Now, for a circular orbit the center of the apparent ellipse coincides with the origin, and consequently an entire group of observations situated in a given quadrant may be transferred bodily to the opposite quadrant, and there be represented by the same ellipse without disturbing the proportionality of the areas described by the apparent distance to the times of their description.

When I made a comparison of the observations with places computed by means of the elements which I had obtained, taking the eccentricity equal to 0.05, I found the agreement of the results satisfactory for those observations which correspond to points in the vicinity of the vertices of the apparent ellipse; that is, for measures whose position-angles do not differ more than ten or fifteen degrees from 20° and 200°. Some of the other observed angles were also well represented, but there was a notable discrepancy between the observed and computed places for the present time, as is also the case with the published orbits quoted above. Since no system of nearly circular elements can account for the rapid change in distance during the past fifteen months, I at once rearranged the observations to correspond to a period of half the length of that which had previously been assumed, and obtained the elements given below. When the mean anomalies corresponding to the observed position-angles were computed by means of these elements and plotted as before, all evidence of systematic variation disappeared. The values, extending over nearly three thousand degrees of mean anomaly, ranged along a straight line with as much precision as could be expected in a quantity which changes so rapidly, 63°.16 a year, and which for the directions given by most of the measures is so largely influenced by possible errors of observation.

My elements are as follows:—

$$\begin{array}{rl}
\text{Period} = & 5.70 \text{ years.} \\
T = & 1901.18 \\
\left.\begin{array}{r} \Omega = \\ \lambda = \\ i = \end{array}\begin{array}{l} 24^{\circ}.1 \\ 179\ .0 \\ 74\ .5 \end{array}\right\} & 1900. \\
e = & 0\ .54 \\
a = & 0''.25
\end{array}$$

Motion retrograde.

λ is here reckoned in the direction of increasing position-angles, so that when M, E, and v are counted as usual in the direction of motion, we have the following formulas for computing the position-angle and distance:—

$$\rho \sin(\theta - \Omega) = r \sin(-v + \lambda) \cos i,$$
$$\rho \cos(\theta - \Omega) = r \cos(-v + \lambda),$$

v and r being found by the usual equations.

An ephemeris computed by means of these elements for each ten degrees of mean anomaly, or for each thirty-sixth part of a revolution is given below. It is given in this form in order that it may be available for the comparison of the observations of any revolution. About a third of the time, however, the motion is so rapid as to render a comparison with the ephemeris roughly approximate only.

In the table giving the Comparison of Observed and Computed Places, the Computed Places have been interpolated from the ephemeris when the motion is slow, and computed directly for the date of observation when it is rapid. The observed position-angles have been reduced to the epoch 1900 by applying the corrections for precession, except for those values which are given in integers and which are approximate only.

An inspection of the columns of residuals, O — C, will show the manner in which these elements represent the observations through no less than eight complete revolutions. While some of the residuals are large, the number of this character is perhaps not greater than is to be expected for a star which has been observed so frequently with instruments of such great variety and which at all times is so difficult. In a considerable number of the cases in which the residuals are abnormally large, the observers have particularly noted that the atmospheric conditions were unfavorable, or that the star for other reasons was difficult to measure. Thus, OTTO STRUVE states that the atmospheric conditions were poor at the time of his observation of 1865.91. WINLOCK and SEARLE regarded their measures of 1866.78 as very unsatisfactory.* ENGELMANN'S observations were made with a small telescope, and the difficulty of the star for such an instrument is a sufficient explanation of the magnitude of some of his residuals. HALL'S angle of 1879.77 is published as uncertain, and LEAVENWORTH states the star was exceedingly difficult with his instrument.

---

* Professor PICKERING has very kindly examined the original records of these observations for me, and states that but little weight should be given to them.

From a casual examination of the column of residuals, it might appear that the late measures of angle by Professor AITKEN are not represented as closely as desirable, and on this account that the several elements require considerable corrections. This may or may not be so. If it is, they should be corrected when the data requisite for the purpose become available. Further observations in other parts of the orbit are desirable to fix with greater certainty the geometrical elements. The periodic time and epoch of periastron passage appear to be well determined. Elsewhere in this number of these *Publications*, Professor AITKEN gives the details of his observations. A reference to his paper will show that he regards his measure of 1900 61 as more reliable than those which he obtained later. I have accordingly given it the preference in the final adjustment of the periodic time and epoch of periastron passage. According to these elements, the angular motion was very rapid during the period covered by these measures, a part of the time amounting to nearly a degree a day, and when we consider the present extreme difficulty of the star, the residuals are more consistent than might have been expected from *a priori* considerations. It may further be remarked in this connection, that all of his measures of angle for the year 1900 will give residuals well within reasonable limits for the possible errors of observation by increasing the date of periastron by only one-twentieth of a year, and if at the same time the periodic time be increased by one one-hundredth of a year, the entire series of residuals from 1852 to 1900 will not be materially affected.

According to my elements, the apparent distance of the companion is greater when it is at periastron (at P in the diagram), than it is before and after that epoch. For a brief period about that time the star should appear distinctly elongated when seen under favorable conditions with a large telescope. Half a year earlier or later it should appear nearly or quite round. From this consideration it appears not improbable that the data may be forthcoming within a few months, which will decide whether the short period given by the elements which I have obtained is correct or not.

LICK OBSERVATORY, November 22, 1900.

COMPARISON OF OBSERVED AND COMPUTED PLACES.

DATES.	COMPUTED.		OBSERVED.		O – C.		No. OF NIGHTS	Observers.
	θ	ρ	θ	ρ	Δ θ	Δ ρ		
	°	″	°	″	°	″		
1852.66	24.3	0.39	22.8	0.48	— 1.5	+0.09	2	OΣ
1853.91	15.3	0.29	12.3	0.27	— 3.0	—0.02	1	OΣ
1854.69	358.0	0.13	Single.		....	......	1	OΣ
1856.57	43.9	0.16	Single.		....	......	1	OΣ
1857.67	28.7	0.35	29.4	0.20±	+ 0.7	—0.15±	2	OΣ
1858.59	22.9	0.38	15.8	0.34±	— 7.1	—0.04±	1	OΣ
1859.65	14.9	0.29	13.0	0.34±	— 1.9	+0.05±	1	OΣ
1861.51	184.5	0.09	236?	....	....	.....	1	OΣ
1865.91	5.7	0.18	22.7	<0.5	+ 17.0	......	1	OΣ
1866.78	219.2	0.09	230.3	....	+ 11.1	......	1	Wl
1866.78	219.2	0.09	110.3	....	—108.9	......	1	Sr
1869.69	24.7	0.38	5	....	— 20	......	1	Du
1869.75	24.3	0.39	10.7	....	— 13.6	......	2	Wl
1869.75	24.3	0.39	17.8	0.44	— 6.5	+0.05	4, 1	Pi
1870.73	17.9	0.33	8	....	— 10	......	1	Du
1874.67	29.4	0.34	22.1	....	— 7.3	......	1	OΣ
1874.73	28.8	0.35	359.9	....	— 28.9	......	1	OΣ
1874.75	28.8	0.35	38.9	0.29±	+ 10.1	—0.06±	1	OΣ
1877.76	329.9	0.06	336.3	0.2 ±	+ 6.4	+0.14±	1	β
1878.63	181.9	0.08	No certain elong.		....	......	1	β
1878.68	174.0	0.07	180?	....	+ 6	......	1	β
1879.77	35.4	0.25	150?	....	....	......	1	Hl
1880.60	27.8	0.36	29.0	0.35	+ 1.2	—0.01	5	β
1881.46	22.4	0.38	22.0	0.38	— 0.4	0.00	4	β
1882.62	13.0	0.26	11.9	0.31	— 1.1	+0.05	1	OΣ
1882.63	13.0	0.26	9.7	0.29	— 3.3	+0.03	3	β
1883.12	1.8	0.15	23	0.17±	+ 21	+0.02±	4	En
1883.55	303.0	.05	307.5	0.21	+ 4.5	+0.16	3	β
1884.70	73.5	0.07	17	0.23±	— 57	+0.16±	3	En
1885.95	30.3	0.33	25.5	0.29	— 4.8	—0.04	6	En
1886.84	24.4	0.39	23.4	0.47	— 1.0	+0.08	2	Hl
1886.87	24.2	0.39	24.5	0.35	+ 0.3	—0.04	6, 2	Sp
1886.91	23.9	0.39	23.2	0.47	— 0.7	+0.08	4	En
1887.78	18.4	0.34	15.2	0.49	— 3.2	+0.15	2, 1	Ho
1887.79	18.4	0.34	15.8	0.44	— 2.6	+0.10	5	Ta
1887.80	18.1	0.34	18.7	0.41	+ 0.6	+0.07	4	Hl
1887.86	17.6	0.33	15.0	0.33	— 2.6	0.00	11, 8	Sp
1888.60	8.1	0.20	33.4	0.35	+ 25.3	+0.15	4, 2	Lv
1888.69	6.0	0.19	9.9	0.25	+ 3.9	+0.06	4	β
1888.90	357.8	0.13	7.0	0.15	+ 9.2	+0.02	10, 14	Sp
1889.51	227.5	0.08	343.2	0.10	+115.7	+0.02	1	β
1889.82	201.1	0.11	193.1	0.2 ±	— 8.0	+0.09	1	Ho
1889.84	199.7	0.11	175.0	0.15	— 24.7	+0.04	3	Sp

COMPARISON OF OBSERVED AND COMPUTED PLACES—*Continued.*

Dates.	Computed.		Observed.		O − C.		No. of Nights.	Observers.
	θ	ρ	θ	ρ	Δ θ	Δ ρ		
	°	"	°	"	°	"		
1890.88	40.8	0.18	Single		....	......	3	Sp
1891.63	30.5	0.32	31.6	0.20	+ 1.1	−0.12	5	β
1891.85	28.8	0.35	23.4	0.21	− 5.4	−0.14	5	Sp
1892.39	25.3	0.38	26.6	0.35	+ 1.3	−0.03	4	β
1892.78	22.9	0.38	21.0	0.33	− 1.9	−0.05	2	Com
1892.91	22.2	0.38	22.8	0.30	+ 0.6	−0.08	2	Sp
1893.84	15.1	0.29	14.9	0.22±	− 0.2	−0.07±	2	Com
1893.86	14.8	0.29	20.1	0.20	+ 5.3	−0.09	2	Bar
1893.93	13.9	0.27	16.8	0.25	+ 2.9	−0.02	6	Sp
1894.85	331.2	0.07	Single		....	......	4	Sp
1895.61	194.5	0.10	Single		....	......	1	Com
1895.70	178.2	0.08	Single		....	......	2	L
1896.68	38.6	0.21	346.8	0.20±	− 51.8	−0.01±	1	Com
1897.72	27.6	0.36	30.9	0.24	+ 3.3	−0.12	4,2	Dob
1897.78	27.3	0.37	28.4	0.40	+ 1.1	+0.03	3	Hu
1897.83	26.5	0.37	29.6	0.33	+ 3.1	−0.04	4	A
1898.49	22.9	0.38	24.8	0.30	+ 1.9	−0.08	4	A
1898.62	22.1	0.38	23.1	0.39	+ 1.0	+0.01	6	Hu
1899.46	15.2	0.30	20.1	0.33	+ 4.9	+0.03	3	A
1899.63	14.0	0.28	21.7	0.17	+ 7.7	−0.11	1	Bo
1899.76	12.4	0.25	10.3	0.23	− 2.1	−0.02	1	L
1899.77	12.3	0.25	11.9	0.28	− 0.4	+0.03	1	Bry
1899.80	10.6	0.23	20.5	0.33	+ 9.9	+0.10	4	Hu
1900.61	319.4	0.06	317.8	....	− 1.6	......	1	A
1900.75	265.7	0.05	287.2	....	+ 21.5	......	1	A
1900.75	265.7	0.05	270.1	....	+ 4.4	......	1	Hu
1900.79	252.8	0.06	275.3?	....	+ 22.5	.....	1	A
1900.86	235.9	0.07	264	...	+ 28	......	1	A

In the above table and in the diagram, the abbreviations used to designate the observers are as follows: OΣ = Otto Struve, Wl = Winlock, Sr = Searle, Du = Dunér, Pi = Pierce, β = Burnham, Hl = Hall, En = Engelmann, Sp = Schiaparelli, Ho = Hough, Ta = Tarrant, Lv = Leavenworth, Com = Comstock, Bar = Barnard, L = Lewis, Dob = Doberck, A = Aitken, Hu = Hussey, Bo = Boyer, Bry = Bryant.

EPHEMERIS.

M.	t—T.	t.	θ	ρ	M.	t—T.	t.	θ	ρ
°	y		°	″	°	y		°	″
0	0.000	1901.180	201.8	0.12	190	3.008	1898.488	22.9	0.38
10	0.158	.338	192.0	0.10	200	3.167	.647	21.9	0.38
20	0.317	.497	170.6	0.07	210	3.325	.805	20.9	0.37
30	0.475	.655	118.5	0.05	220	3.483	.963	19.8	0.36
40	0.633	.813	71.4	0.07	230	3.642	1899.122	18.7	0.34
50	0.792	.972	53.6	0.11	240	3.800	.280	17.5	0.33
60	0.950	1902.130	45.4	0.15	250	3.958	.438	16.0	0.31
70	1.108	.288	40.6	0.19	260	4.117	.597	14.4	0.28
80	1.267	.447	37.4	0.23	270	4.275	.755	12.4	0.25
90	1.425	.605	35.0	0.26	280	4.433	.913	9.9	0.22
100	1.583	.763	33.1	0.29	290	4.592	1900.072	6.5	0.19
110	1.742	.922	31.5	0.31	300	4.750	.230	1.3	0.15
120	1.900	1903.080	30.1	0.33	310	4.908	.388	352.3	0.11
130	2.058	.238	28.9	0.35	320	5.067	.547	332.3	0.07
140	2.217	.397	27.8	0.36	330	5.225	.705	282.3	0.05
150	2.375	.555	26.7	0.37	340	5.383	.963	235.1	0.07
160	2.533	.713	25.8	0.38	350	5.542	1901.022	215.4	0.10
170	2.692	1903.872	24.8	0.38	360	5.700	1901.180	201.8	0.12
180	2.850	1904.030	23.8	0.39					

ON THE PROGRESS MADE IN THE LAST DECADE IN THE DETERMINATION OF STELLAR MOTIONS IN THE LINE OF SIGHT.*

By H. C. VOGEL.

After the early attempts at the determination of the component in the line of sight of the motion of the stars by means of the spectroscope, which were made in 1868 by HUGGINS, in London, and in 1871 by myself at Bothkamp, on a few stars, extensive observations of this kind were conducted at the Observatory at Greenwich, extending over a period of thirteen years. The great persistence exhibited by MAUNDER in these observations, which were placed in his charge, is worthy of the more recognition in view of the slight interest which astronomers then generally had in the physical side of astronomy, and especially in view of their skeptical attitude toward the application of the

---

*Reprinted from the *Astrophysical Journal* for June, 1900.

spectroscope for determinations of motion. There was, indeed, some basis for this, inasmuch as a contention had arisen among the physicists as to whether the so-called Doppler's principle, which was recognized as experimentally correct for sound-waves, and which also permitted an easy theoretical explanation, could be justifiably transferred directly to light-waves. The striking proofs* of the admissibility of extending Doppler's principle to moving sources of light, furnished by the astrophysicists in the course of time, gradually silenced their opponents, foremost among whom were Van der Willigen and Spée. We must not omit to mention, however, that an exhaustive theoretical treatment and explanation of the problem has not been given even up to the present time.

The protracted Greenwich observations of the stellar motions, which included forty-eight of the brightest stars, have demonstrated that direct observations with medium-sized instruments cannot furnish results whose uncertainty is of a less order than the average motion of the stars themselves. When the dispersion is just sufficient to permit the definite recognition of the displacement, which at most is slight, the intensity of the spectrum of even the brightest stars in a medium-sized instrument is too low to permit even a tolerably accurate measurement. A further reason for the small success doubtless lay in the unsuitability of the apparatus, which was especially lacking in stability.

When I made the first attempt in 1887, with the assistance of Professor Scheiner, to record photographically the displacements of the lines in stellar spectra, and then to measure them as accurately as possible on the spectrograms, it very soon appeared that this constituted a very marked advance in the determination of these motions, which are so significant in stellar astronomy. The accuracy of the observations was increased more than eightfold with the apparatus constructed in 1888; the probable error, which in the Greenwich observations averaged $\pm 22^{km}$ for an evening, being brought down in the Potsdam observations to an average of $\pm 2.6^{km}$. We may therefore fairly say that the determination of motions in the line of sight thus first received a substantial basis in the spectrographic method, and thereby the widest prospects were opened for a period of new investigations and discoveries.

---

*I would refer to the introduction to Part I of Vol. VII of the Publications of the Potsdam Observatory, as well as to Dunér's *Recherches sur la Rotation du Soleil.*

This success is doubtless due in the first instance to the application of photography; but we must not leave out of consideration that it is also in part due to the fact that a complete departure from previous principles was made in the construction of the apparatus, and an instrument was completed exclusively for this definite purpose, possessing the greatest possible stability. While spectroscopes are even yet constructed so that they can serve for many purposes,—permitting variations in the dispersion, and allowing measurements to be made in the most widely separated parts of the spectrum,—the Potsdam instrument photographs only a small portion of the spectrum in the neighborhood of the hydrogen line $H\gamma$. Its dispersion was so chosen that with sufficient sharpness of the spectrum a difference between the setting on a line of the star spectrum and one of the comparison spectrum could be determined under the measuring-machine with an accuracy corresponding to a motion of but a few kilometers. Where the spectrum of the star permitted, it was further arranged so that not only the position of a single line in the stellar spectrum was referred to that of a corresponding line in the comparison spectrum, but several lines were employed for the determination of the displacement. The accurate identification of the lines in the star spectrum was also attempted during the measurement by direct comparison with a plate of the solar spectrum.

I can restrict myself to these general statements, since the apparatus, as well as the methods of measuring the plates and reducing the observations, are sufficiently well known from the full descriptions given in Part I of Volume VII of the *Publications of the Astrophysical Observatory*. But I desire to add something for the accurate description of the state of this branch of science at the conclusion of our series of observations at the beginning of the decade just past, and I also cannot withhold a critique of our observations from the standpoint gained by wider experience.

I would first point out that several of the precautions taken in the observations, which might appear as carried too far, were conditioned by an unsuitable telescope. The Potsdam 11-inch refractor is of very light construction, and has a wooden tube which occasions a strong effect of temperature in the alteration of the focal length. Although the wooden tube is conical, it has a very appreciable flexure.

In consequence of the slight stability of the telescope, an arrangement had to be thought out for bringing the star accurately upon the slit and holding it there in the proper position during the exposure of the photographic plate. This was accomplished by the simple means of simultaneously observing with a small telescope the image of the slit, illuminated by a Geissler tube, and the image of the star, reflected from the front face of the first prism. This method of guiding appears to have been adopted later by all observers who have undertaken determinations of velocities by the spectrographic method.

It is no longer indispensable with some of the more recent instruments, as for instance the great Potsdam refractor, since a guiding telescope of nearly the same focal length is attached to the telescope itself.

Although it was my endeavor to develop something entirely new in constructing the stellar spectrograph in 1888, in respect to the prisms I was under the influence of the times, and chose the compound prisms known as Rutherfurd's, which then were considered the most excellent, and in fact possessed the advantage of giving less deviation for the same dispersion, and hence less curvature of the spectral line, and which caused less loss by reflection on account of the less oblique incidence of the rays. Extensive investigations made here at a later time have shown that simple prisms are preferable, and elsewhere the use of prism systems has continually decreased. In observations with the spectrograph we have had the experience that strains occur in the cemented prisms at temperatures below —2°, causing a diffuseness of the spectra. A consequence of the above mentioned large flexure of the wooden tube of the 11-inch refractor may be that in many positions of the telescope the collimator and the prism are not fully utilized; except for a slight loss of light, this would have no injurious effect on the observations under conditions of good adjustment, perfect surfaces of the prisms, and complete homogeneity of the masses of glass used for the prisms.

As above stated, however, tensions in the prisms and consequent departures from homogeneity in the glass have shown themselves distinctly at low temperatures, which have caused not only a diffuseness of the spectra and a consequent diminished accuracy, but also have not been without effect on the displacement of the lines. Although this effect may have been exceedingly slight in most cases, it may nevertheless have become appreciable in unusual positions of the telescope, such as occur for stars near the pole, and possibly the large discrepancies for a few stars between our observations and those of other observers may be thus explained. In our observations we have always used the telescope in that position only (east or west) in which the optical axis of the collimator and telescope were adjusted. It was not possible to determine subsequently the effect of a lack of coincidence of the two axes on the displacement of lines in the spectra; this, moreover, could hardly have been determined at the time of observation, since it depends on the changes of temperature in the prisms, and the tension thereby occasioned, as well as upon the declination and the hour-angle. The determination of the true temperature of the prisms is in general beset with difficulties, and the determination of the temperature of the separate parts of the prisms is, therefore, hardly to be thought of. We might infer that the errors arising would balance each other in a great number of observations made under the greatest variety of conditions. It would, however, probably be possible to obtain later data as to the errors dependent upon the position of the spectrograph, from a comparison of the Potsdam observations with the results obtained by other observers and with other instruments.[*] Such errors are hardly to be expected in the newer instruments with simple prisms, and having greater stability of the telescope. We have most carefully studied the effect of the temperature on the focal length of the objective of the refractor and upon the focal length of the objectives of the collimator and camera, as well as the varying dispersion of the prism with the temperature, and we have taken them into account both in the observations and in the reductions of the measures.

The hydrogen spectrum was in nearly all cases used as a comparison spectrum, though attempts were made to use the magnesium line λ 448 $\mu\mu$, which possesses the advantage of being very sharp in some star spectra, while the *H*γ line is broad and diffuse; but without success, since this line is diffuse in the spark spectrum. The iron spectrum may also be used, and I have pointed out the advantages gained in the use of this spectrum, as well as that of other metallic substances, have described the method of observation, and have illustrated it by an example — the spectrum of *Sirius*.* It would have been better for this purpose to have used the spectrum of α *Cygni* or of a star of the second class, because the lines in the spectrum of *Sirius* are exceedingly fine. For *Sirius* the probable error of the motion in the line of sight obtained from the difference between a single line in the star spectrum and a single line in the comparison spectrum is $\pm 1.34^{km}$; so by the use of nine such pairs the probable error of the measurements of the plate would not be more than $\pm 0.45^{km}$.

---

[*] At present I am acquainted with determinations of the motions of only something more than half of the objects observed in Potsdam, made by Bélopolsky, Campbell, Newall, and Lord, for the great part of which I am indebted to letters of Messrs. Bélopolsky and Campbell. The comparison of these with the Potsdam observations leads to the following provisional results. The departure of the Potsdam results from those of the above observers averages ± 2.8^{km} for 23 objects, and the comparison shows with some certainty that the Potsdam values on the average are 1.2^{km} too large for stars of negative motion, and 0.7^{km} too small for those of positive motion. This constant departure is more clearly pronounced if we consider Campbell's observations only. Taking the mean from 19 objects the departure V. S. — C. = ± 2.7^{km}; the negative velocities were found on the average to be 2.5^{km} larger and the positive velocities 1.6^{km} smaller by Vogel and Scheiner than by Campbell. If we apply these average values to the observations, the mean value of the difference V. S. — C. comes out as ± 2.0^{km}.

The observations could be made on only forty-seven of the brighter stars, since the spectrum of a star fainter than 2.3 magnitude with an exposure of about an hour did not have sufficient intensity to be measured with accuracy. With a longer exposure the practically unavoidable changes in temperature produced such an influence on the spectrograph that the accuracy of the observation was impaired. As a guard against accidental errors, it was intended that each star should be observed on at least two nights. At the time when these observations were begun, the possibility that a star might show changes in its motion in the line of sight, in a short time, had not been thought of; yet out of these forty-seven stars four had already been found to have a periodic variation during the progress of the work.

The object of this work on the motion of stars in the line of sight, completed in 1891, was first to demonstrate the usefulness of the spectrographic method for instruments of medium size, and further, by means of a thorough and detailed description of methods, to enable an observer equipped with better instruments to carry on observations of this character; and possibly to give the method still further development. There was no need of our repeating these observations in the next few years with the same instrument, while we hoped that in the near future we should be able to extend them with more powerful optical means. Unfortunately the realization of this hope was deferred from year to year, and not until the present year did it again become possible for us to carry on regular observations at the Potsdam Observatory — this time, however, with instruments of the highest order of excellence.

---

* *Sitz. d. k. Acad. d. W. Berlin*, No. 28, 533, 1891.

Now, while the seed which we planted ten years ago has not hitherto received in Potsdam the nourishment which we could have wished, yet I have the pleasure of knowing that it has found nourishment in other places, so that it has thriven greatly, and has already blossomed beyond our highest expectations.

In 1890 and 1891 KEELER made his beautiful observations on the radial velocity of the brighter nebulæ, by means of a grating spectroscope attached to the great refractor of the Lick Observatory. Fourteen nebulæ were examined for motion, and the determinations of these motions are of remarkable accuracy, considering the great difficulty of the observations. The probable error of the result for each nebula, a result which is the mean of several observations, is on the average only $\pm 3.2^{km}$. Of the fourteen nebulæ, nine have a negative and five a positive motion, referred to the Sun. The average motion is 27^{km}, and therefore, if we are justified in drawing a conclusion from so small a number of observations, is of the same order as that of the brighter stars. The greatest velocity, -65^{km} per second, is that of the well-known planetary nebula *G.C.* 4373, H IV 37. It exceeds by about 10^{km} that of α *Tauri*, which has the greatest velocity of any of the brighter stars of the northern heavens.

While making these observations on nebulæ, KEELER determined the radial velocities of α *Bootis*, α *Tauri*, and α *Orionis*. He found for the velocity of α *Bootis*, from nine measures during 1890 and 1891, a value of $-6.8^{km} \pm 0.3^{km}$; for α *Tauri*, on three evenings, $+55.2^{km}$, and for α *Orionis*, on two evenings $+14.0^{km}$ per second. The probable error of a single evening's observations, deduced from the results for the three stars, averages $\pm 1.8^{km}$.

The Potsdam observations made from 1888 to 1890 give for these three stars the values: -7.6 ± 0.6^{km}, $+48.5^{km}$, and $+17.2^{km}$. A better agreement, considering the complete independence and entirely different character of the methods used (KEELER made his measures on the D lines), could hardly be expected. With the Lick refractor, which exceeds the Potsdam

11-inch refractor some eight times in light-gathering power, it has therefore been possible to determine the motions of the brighter stars, by direct observation, with about the same accuracy as with the Potsdam refractor by the spectrographic method.

About the end of the year 1891, the great Pulkova refractor of 76^{cm} aperture was provided with a spectrograph, built exactly according to the model of the Potsdam instrument, and like the latter provided with two Rutherfurd prisms. The instrument was so arranged that the prism-box could be removed, and another, containing only a single prism, substituted for it when faint objects were to be observed with small dispersion. Since the refractor had been intended primarily for micrometric work, and only secondarily for spectroscopic, the telescope and observing-chair had been designed mainly with reference to the convenience of the observer at the micrometer. For this reason BÉLOPOLSKY had to contend with many difficulties before he finally succeeded, after making a number of considerable changes in the telescope and the observing-chair, in making spectrographic observations with accuracy. The very unsuitable climate made it necessary for him to abandon his original plan of observing the motions of the fainter stars, a plan which may be regarded as an extension of the Potsdam observations. He therefore selected special objects from among the variable and double stars for his observing-list, and made observations of their motions.

Among his valuable researches should be mentioned his investigations of δ *Cephei*[*], in which he demonstrates the existence of a periodical variation in the velocity of this star in the line of sight, which could be brought into good agreement with the period of its light curve, $5^d\ 9^h$. In the case of η *Aquilæ*[†] he discovered a variation in the velocity which found an explanation in the period of light-variability of $7^d\ 4^h$; and finally he found a change in the velocity of α^1 *Geminorum*[‡] with a period of $2^d\ 23^h.5$. It soon appeared that the line of apsides of this double-star system was in rapid revolution, and from careful investigation the period of this motion was found to be 4 years 40 days.[§]

As the interesting double spectrum of the well-known variable β *Lyræ* was known, from spectrographic observations, to contain pairs of bright and dark lines, and since changes in the relative positions of these lines had been discovered which were connected in some way with the period of variability of $12^{d}.9$, Pickering attempted to calculate the orbit of this hypothetical double star from measures of the distances between the double lines at different phases of the light period. He found a relative velocity of the components of 482^{km} per second, and a diameter of the orbit, assuming it to be circular, of 85.3 million kilometers. I have more recently pointed out that the distance between the lines, and therefore the relative velocity of the components, has been taken to be too large, by not taking into account a probable overlapping of the lines; since the above value leads to an enormous mass ($150\odot$) of the system. Bélopolsky has published an extensive investigation[*] of *β Lyræ*, based on observations made with the Pulkova refractor, in which are contained many interesting details concerning the changes which take place in the pairs of bright and dark lines during the period of the star's variability. From his measures of the hydrogen line $H\beta$ he found an orbital velocity of 89^{km} per second, a semiaxis of 15 million kilometers, and hence a mass of the system of the same order as that of the Sun.

---

[*] *Astrophysical Journal*, Vol. 1, 160. *A. N.*, Vol. 140, 17.

[†] *Mem. Spettr. Ital.*, Vol. 26, 101.

[‡] *Bull. Acad. St. Petersbourg*, No. 4, 341. *Astrophysical Journal*, Vol. 5, 1.

[§] *Mem. Spettr. Ital.*, Vol. 26, 101, and Vol. 28, 103.

In 1894, while examining a large mass of observations of *β Lyræ* made with a small single-prism spectrograph attached to the photographic refractor of the Potsdam Observatory,[†] I found clearly a certain agreement between the relative displacement of the lines and the period of light variability, but not of the simple character assumed by Bélopolsky. The variation in the distance between the bright and dark line $H\zeta$, especially, seemed to correspond to a period much longer than the period of the light variation, so that a system of two bodies was no longer adequate to explain the phenomena observed in the spectrum. Now since it has been shown by Myers that the light curve is very satisfactorily represented under the assumption of a double-star system, we are compelled to introduce explanations which depend upon phenomena of a physical nature.

Bélopolsky[‡] thereupon, in 1897, resumed his investigations, and from them there is no doubt that we have come nearer to a decision as to the nature of *β Lyræ*. In his measures he disregarded the bright lines altogether, and restricted himself to the dark magnesium line λ 448 $\mu\mu$, which has no companion emission line, and thus freed them from the influence of a partial overlapping. By so doing he was able to obtain results which were referable to the case of a simple double star without further complication. He found for the orbital velocity 178^{km} per second, for the semiaxis of the orbit 31.9 million kilometers for the distance between the two components 47.5^{km}, and for their masses respectively 9 and 18 times the Sun's mass.

---

[*] *Bull. Acad. St. Petersbourg*, N. S., No, 4, 341. *Mélanges mathem. et astr.*, Vol. VII. Livr. 3, 1893.

[†] *Sitz. d. K. Akad. d. W. Berlin*, 1894, 115.

[‡] *Mem. Spettr. Ital.*, Vol. 26, 135; also Tikhoff, *ibid.*, Vol. 26, 107.

Bélopolsky has also found variable motion in λ *Tauri*, ζ *Geminorum*, and θ *Ursæ Majoris*,[*] so that his contribution to the discovery of spectroscopic binaries consists of seven objects.

It is of interest to note here the great velocity of -70^{km} per second, referred to the Sun, which Bélopolsky has found for ζ *Herculis*.[†] Campbell,[‡] at the Lick Observatory, has confirmed this observation and obtained a value of -70.3^{km}, while Deslandres,[§] at Paris, obtained a value about 10^{km} smaller. In this connection I may remark that Campbell has found in η *Cephei* the greatest known velocity of a star in the line of sight (-87^{km} per second). This velocity would probably be reduced somewhat if we were to take into account the motion of the solar system. Assuming the co-ordinates of the apex of the Sun's way to be $\alpha = 267^\circ$ and $\delta = +31^\circ$, and the velocity of the Sun to be 17^{km} per second, we get for the absolute component of the velocity in the direction of the Sun, -74^{km} per second for η *Cephei*, -54^{km} for ζ *Herculis*, and -51^{km} for the nebula *G. C.* 4373.

In publishing his observations of ζ *Herculis*, Deslandres made a remark concerning the Paris telescope of 1.2 meters aperture, to which his spectroscope was attached, from which it appears that the stability of the telescope is hardly what it should be for such delicate investigations; and, possibly because the mirror did not unite perfectly all the rays on the slit, the exposure had to be made 50 per cent. longer than with the Pulkova refractor, under presumably less favorable atmospheric conditions. In these unsuitable conditions may also be found the reason why so few observations of stellar motion by Deslandres have been made known. He has published beautiful threefold enlargements of the original spectrograms [||] of the four stars α *Aurigæ*, β *Aurigæ*, α *Canis Majoris*, and γ *Pegasi*, which are specially remarkable for the great length of spectrum which his apparatus is capable of defining sharply. With the exception of a series of observations of α *Aquilæ*, nothing further is known to me of work on the motions of stars at the Paris Observatory.

---

[*] *A. N.*, Vol. 145, 281; also Vol. 149, 239, and Vol. 151, 39.

[†] *A. and A.*, February, 1894. *A. N.*, Vol. 133, 257.

[‡] *Astrophysical Journal*, Vol. 8, 157.

[§] *C. R.*, Vol. 119, 1252.

[||] *Spécimens de Photogr. Astronomiques. Obs. de Paris*, 1897.

At the suggestion of POINCARÉ of Paris, DESLANDRES has, on the other hand, made spectrographic researches on the motion of the planets, and on the rotation of *Jupiter*,[*] which are of importance. The investigations showed, in accordance with POINCARÉ'S assumptions, that in the case of a body which shines by diffuse reflected light, the displacement of lines in its spectrum depends not only on the motion of the body with reference to the observer, but also on the motion of the body with reference to the source of light by which it is illuminated.[†] The observations on the rotation of *Jupiter* have been repeated and confirmed by BÉLOPOLSKY.

The beautiful results which KEELER obtained by the spectrographic method at the Allegheny Observatory on the rotation of the ring system of *Saturn*, should be mentioned in this connection. By these observations it was shown that *Saturn's* rings consist of separate small bodies which revolve about *Saturn* in obedience to KEPLER'S laws, and cannot be regarded as a rigid body, thus furnishing a practical confirmation of the conditions demanded by theory.[‡] These interesting observations have been repeated by CAMPBELL, BÉLOPOLSKY, and DESLANDRES.

The first attempts to prove the truth of Doppler's principle, by showing that there is a displacement of the lines in the spectrum of the edge of the Sun near the equator which corresponds to the known equatorial velocity obtained from observations of sun-spots, were made by me twenty-nine years ago. In the course of time these observations have been frequently repeated with improved instruments. DUNÉR, in Lund, has undoubtedly carried out the most thorough investigation of the rotation of the Sun in different zones, by means of spectroscopic methods.[§]

---

[*] *C. R.*, Vol. 120, 417.

[†] *A. N.*, Vol. 139, 241.

[‡] KEELER used in these observations a spectrograph composed of three simple prisms, which produced a total deviation of 180°. From a few original negatives of the solar spectrum and several excellent negatives of planetary spectra, which he kindly sent me, I was able to see that the apparatus is very similar to the Potsdam spectrograph of 1888, both as regards dispersion and resolving power. The dispersion of KEELER'S apparatus is about one-twentieth greater than that of the Potsdam spectrograph, while the resolution of close lines is almost exactly the same in both instruments. Perhaps KEELER'S apparatus is slightly superior to the Potsdam apparatus in this respect.

[§] N. C. DUNER: "Recherches sur la Rotation du Soleil." *Nova Acta Reg. Soc. Sc. Ups.* Series III.

He was induced to make these observations because, in the beginning of the 'eighties, the trustees of the Lars Hjertas Minne endowment expressed a desire to have the spectroscope used for a careful investigation of the question whether the wave-length of light really varies directly as the velocity of the source of light, as required by the Doppler-Fizeau principle, and had expressed their willingness to grant sufficient money for a suitable spectroscope.

To give some idea of the results of his observations, which were made during the summer months of the years 1887, 1888, and 1889, I have inserted the following table of the means for various heliocentric latitudes, with their probable errors:—

Heliocentric latitude.	Velocity in km.	Number of observations.	$\xi \cos \phi$	ξ
0°.4	1.98 ± 0.013	107	14°.14	14°.14
15 .0	1.85 0.013	104	13 .19	13 .66
30 .0	1.58 0.014	104	11 .31	13 .06
45 .0	1.19 0.014	106	8 .48	11 .99
60 .0	0.74 0.012	107	5 .31	10 .62
74 .8	0.34 0.013	107	2 .45	9 .34

Shortly before the completion of DUNÉR'S researches there appeared two extended investigations by CREW† on the same subject, which led to the result that the absorbing layer of the Sun rotates with a uniform angular velocity, while DUNÉR'S observations cannot be harmonized with the assumption of a constant angular velocity, as is shown by the table, in which the angular velocity (ξ and $\xi \cos \phi$) is given in the last two columns. This is not the place to discuss the difference between the results obtained by the two observers; for it was merely my purpose to mention the beautiful observations which have been made in this field, and to show what great accuracy can be given to spectroscopic observations of motion when there is sufficient light. The observations of DUNÉR agree very well with the law of the rotation of the Sun derived from the observations of the sun-spots.

With regard to the above-mentioned desire of the trustees to ascertain whether the change in the wave-length of light is proportional to the velocity of the luminous source, DUNÉR'S observations have shown that, within the errors of observation, the simple form of Doppler's principle is valid, and the influence of possible higher terms is not recognizable.

---

† HENRY CREW: "On the Period of the Rotation of the Sun as Determined by the Spectroscope." *Am. Jour. Sci.*, Vol. 35, 151, and Vol. 35, 204.

Through the generosity of Mr. D. O. MILLS, Professor HOLDEN, at that time Director of the Lick Observatory, was able to have a spectrograph constructed for the Observatory about the middle of the nineties, to be used exclusively for determining stellar motions in the line of sight. In the October, 1898, number of the *Astrophysical Journal*, Professor CAMPBELL has given an extended description of this instrument, which mainly through his endeavors has become the most noted instrument of its time.

Attached to the great 36-inch refractor of the Lick Observatory, used under the most excellent atmospheric conditions, and in the hands of a circumspect and careful observer, the Mills spectrograph has in the last few years achieved surprising results. The spectrograms taken with it possess, on the average, a sharpness which excels that of even the best spectrograms taken with the Potsdam apparatus of 1888, and the resolving power of the instrument is much greater. Through the kindness of Messrs. KEELER and CAMPBELL, I received last year two original negatives, one of γ *Andromedæ*, and the other of η *Pegasi;* so that I was able to thoroughly assure myself of their excellence. They are marked as being above the average excellence, and their measurement is a real pleasure; yet even with such plates great care and long experience are required to obtain uniformly consistent results.

With spectra which contain many lines, and which differ considerably from the solar spectrum, the use of a solar spectrum in measuring the plates cannot well be avoided. In many spectra, on the other hand, especially those with strong iron lines, the stellar and comparison spectra can be compared directly by means of HARTMANN'S interpolation formula.* The amount of the shifting of a known line in the star spectrum can be exactly determined even if there is no identical line in the comparison spectrum; for instance, the lines of hydrogen and clèveite gas can be compared with iron lines in the comparison spectrum.

On CAMPBELL'S plates the probable error of the determination of the distance between a stellar line and the corresponding comparison line may be taken as ± 1.2^{km}, and since from ten to twenty measurable lines may easily be found in the spectrum of a star of class II, the probable error of the mean of the measures on a single plate may be reduced to about ± $\frac{1}{3}^{km}$. Slight was frequently observed at Potsdam during the years 1888–1891, this peculiarity of its spectrum escaped us, and the explanation of the fact that most of our spectrograms of α *Aurigæ* are ill-defined and the lines quite extraordinarily broadened, was only given later, by the investigations of CAMPBELL. The days on which the spectrograms obtained were good and sharp, are those on which the two spectra were superposed, and our early observations have now at least given us the means of arriving at a more accurate value of the period $(104^{d}.1 \pm 0^{d}.2)$. By means of observations with the new Potsdam refractor and spectrograph, we have been able to confirm CAMPBELL'S observations, both of α *Aurigæ* and α *Ursæ Minoris.*[*]

---

* *Publ. des Astrophys. Obs. zu Potsdam*, Vol. 12, No. 42.

When we consider that researches on the motions of stars in the line of sight have been begun and are being carried on with good results by NEWALL, in Cambridge, and by LORD, at the McMillin Observatory in Ohio; that in Meudon a double refractor of the same size as the Potsdam instrument has been set up, and provided with a spectrograph, with which DESLANDRES[†] has already succeeded in showing that δ *Orionis* is a star with variable velocity; that further, the largest instrument in the world, Yerkes refractor at Williams Bay, will also be used for this purpose, and that GILL, with the double refractor of the observatory at the Cape of Good Hope, will extend the same researches to the southern heavens, we may confidently expect that our knowledge of the stellar system to which we belong will be increased as much in the new century upon which we are entering as our knowledge of the solar system has been increased in the century just past. The energy with which some of the largest observatories in the world are participating in the work is most encouraging, for the amount of work to be done has grown most unexpectedly during the last decade, through the discovery of so many stars having a variable velocity in the line of sight.

In closing this review, I should not wish to leave unmentioned the fact that in one case the application of the Doppler-Fizeau principle can no longer be regarded as valid; I refer to the

---

placements from the mean position are about equal. Assuming the period to be $104^{d}.1$ and the maximum relative velocity to be $\pm 30^{km}$, and assuming provisionally that the orbit is nearly circular, with its plane in the line of sight, I have found, for the combined mass of the stars, $m+m_{1}, = 2.3 \odot$, and for their distance, 85.3 million ^{km}.

[*] It should be added here that the discovery of the duplicity of the lines of α *Aurigæ* was made independently, and almost simultaneously, by NEWALL, of Cambridge, England.

[†] *C. R.*, Vol. 130, No. 7.

interpretation of the pairs of bright and dark lines which are found in the spectra of the new stars. When this peculiarity of the spectra of new stars was discovered, it was very natural that the relatively strongly displaced emission and absorption lines should be ascribed to the spectra of two bodies, whose motions in the line of sight were oppositely directed. Corresponding to the great displacement of the lines, velocities were arrived at which, in comparison with the mean velocity of other heavenly bodies whose motions have been spectroscopically determined, must be characterized as perfectly enormous — more particularly since it was improbable that the whole motion of the bodies should be in the line of sight.

But since in the stars which have appeared more recently, *Nova Normæ* and *Nova Carinæ*, the same pairs of bright and dark lines were found, in which, as in the spectrum of *Nova Aurigæ*, the emission line lay on the less refrangible side; and since similar lines can be observed in the spectra of *β Lyræ* and *P Cygni* (the *Nova* of 1600); and particularly since no change in the distance between the bright and dark lines could be detected during the whole of the first apparition of *Nova Aurigæ*, and the lines remain unchanged in position in the spectrum of *P Cygni* — while in *β Lyræ*, though they vary during the star's period, the changes are never so great as to reverse the positions of the dark and bright lines — doubts as to the applicability of Doppler's principle to such cases appeared to be more and more fully justified.

The assumption that we are here concerned with phenomena of a purely physical nature gained a firmer basis through the researches of HUMPHREYS and MOHLER, EDER, and WILSING,* on the changes produced in spectral lines by high pressure. It was found that under high pressure pairs of bright and dark lines could be produced in metallic spectra, in which the emission line always lay on the less refrangible side.

These observations are to be regarded as only first beginnings; but doubtless through them a wide field of highly interesting research is opened, in which the astronomer may hope for the zealous support of the physicist. The veil which has enveloped anew our knowledge of the nature of the temporary stars will certainly be lifted, when experiment shall yield results which harmonize with the phenomena observed in them; and not until then will the time come to frame hypotheses respecting the origin of the abnormal conditions of pressure in their atmospheres.

---

* "Ueber die Deutung des typischen Spectrums der neuen Sterne." *Sitz. d. K. Akad. d. W. Berlin*, Vol. 24, 425. 1899.

It is quite possible that, as observations of motions in the line of sight become more and more refined, the conditions of pressure in the atmospheres of the stars can no longer be neglected, although it may be assumed that the pressure in the atmospheric layers from which the light comes to us is neither subject to great variations for any individual star, nor varies widely for different individuals. Even if this should not be true, the means of arriving at accurate results for stellar motion, and at the same time of gaining information concerning the conditions of pressure in the stellar atmospheres, is to be found in the use of different metals for comparison spectra.

THE ORBIT OF *99 HERCULIS=A. C.* 15.

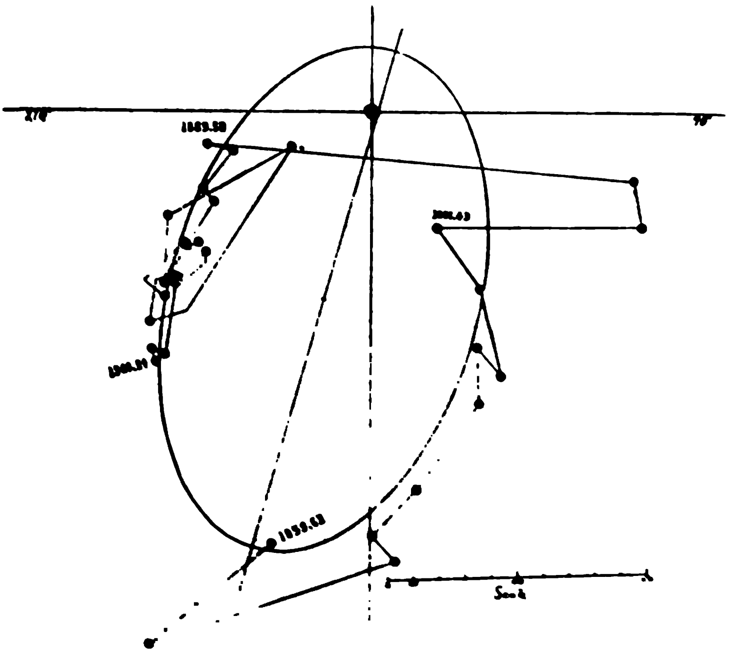
By R. G. Aitken.

The faint companion to *99 Herculis* was discovered by **Alvan Clark** in 1859, and the first measures of it were secured by **Dawes** in the same year. **Otto Struve** measured it on five nights during the next twenty years, but otherwise it was wholly neglected until **Burnham** began work with the 18½-inch Dearborn refractor in 1878.

The measures indicated motion, but whether this was rectilinear or orbital it was impossible to say until 1889. In that year **Burnham** observed the pair with the 36-inch telescope of the Lick Observatory, and found that the small star had passed over an arc of more than 180° since his observation in 1881. It was at once evident that the system was binary, with a moderately short period.

In the last ten years the star has been observed frequently, but the great difference in the brightness of the two components, and their small angular separation, make it a difficult object, and the measures are discordant.

The following are all the published observations:—



THE ORBIT OF 99 *HERCULIS*

DATE.	Pos. Angle.	Dist.	*n*.	Observer.	O − C.	
					Δ θ	Δ ρ
1859.63	347°.2	1″.70	2	DAWES	− 2°.4	− 0″.03
60.30	337 .4	2 .22	1	O. STRUVE...	− 12 .9	+ 0 .50
66.68	3 .1	1 .73	1	"	+ 5 .0	+ 0 .15
68.50	0 .1	1 .63	1	"	− 0 .7	+ 0 .11
72.56	7 .0	1 .46	1	"	− 0 .5	+ 0 .12
77.56	20 .7	1 .19	1	"	+ 1 .3	+ 0 .15
78.46	24 .4	0 .99	3	BURNHAM....	+ 2 .0	+ 0 .01
79.47	26 .5	1 .13	1	"	+ 0 .1	+ 0 .23
80.53	31 .6	0 .80	2	"	+ 0 .5	± 0 .00
81.43	29 .4	0 .51	1	"	− 6 .9	− 0 .22
83.65	75 .4	1 .14	2	O. STRUVE...	...	....
88.54	67 .2	1 .05	1	"	...	....
88.73	Apparently single.		36-inch.	BURNHAM....	....	....
89.50	281 .2	0 .65	1	"	+ 16 .7	+ 0 .22
90.45	285 .1	0 .56	3	"	+ 6 .6	+ 0 .03
91.56	294 .4	0 .72	3	"	+ 5 .1	+ 0 .07
92.40	299 .2	0 .70	3	"	+ 4 .0	− 0 .04
94.74	305 .7	0 .88	1	COMSTOCK...	− 0 .7	− 0 .07
95.30	307 .0	0 .84	1	SEE	− 1 .3	− 0 .15
95.46	309 .5	1 .04	6	BARNARD....	+ 0 .6	+ 0 .04
95.61	297 .2	0 .89	1	HOUGH	− 12 .1	− 0 .13
95.65	293 4	0 .34	2	LEWIS	− 16 .0	− 0 .68
95.73	313 .4	....	2–0	MOULTON ...	+ 3 .7	....
95.73	315 .2	1 .18	3–2	SEE	+ 5 .5	+ 0 .15
95 80	309 .6	1 .00	3	COMSTOCK...	− 0 .3	− 0 .03
96.62	305 .0	0 .85	2	LEWIS	− 7 .3	− 0 .25
96.65	311 .9	1 .07	3	COMSTOCK...	− 0 .5	− 0 .03
96.70	310 .3	0 .84	4–3	AITKEN......	− 2 .3	− 0 .26
97.54	311 .1	1 .00	4	"	− 3 .8	− 0 .15
98.54	310 .4	0 .99	2	LEWIS	− 6 .9	− 0 .23
99.29	319 .6	1 .23	2	HUSSEY......	+ 0 .7	− 0 .04
99.34	317 .3	1 .25	3	AITKEN	− 1 .7	− 0 .02
1900.54	319 :0	1 .27	4	"	− 2 .4	− 0 .06

All the complete observations have been plotted to scale, and are represented in the figure (p. —) by the small black circles. Their order in time is indicated by the broken line. A mere inspection of the figure shows how impossible it is to satisfy all of the observations. Some of the most discordant ones must be entirely neglected. Indeed, it is very doubtful whether the measures by OTTO STRUVE in 1883, and especially those in 1888, refer to the real companion at all. In the latter year the distance was almost certainly as small as 0″.5, and the pair therefore exceedingly difficult. In fact, BURNHAM noted it as single with the 36-inch refractor in that year.

After many trials, the ellipse shown in the figure was adopted as the best that could be drawn at present, and from it the following set of elements was derived:—

$P = 63.0$ years. $\Omega = 154^\circ.7$
$T = 1887.0$ $i = 24.7$
$e = 0.76$ $\lambda = 11.3$
$a = 1''.00$ $n = +5.7143$

How nearly these elements satisfy the observed positions may be seen by examining the two columns of residuals following the names of the observers in the table.

A comparison of the above elements with those previously published by GORE and SEE, seems to indicate that the eccentricity and the major semiaxis of the orbit, and the time of periastron passage are fairly well known. The other elements differ widely, as the following tabulation shows:—

	P	T	e	a	Ω	i	λ
GORE...	53.55	1885.58	0.7928	1''.12	50°.1	38°.6	110°.73
SEE.....	57.5	1887.30	0.806	1 .163	77 .0	35 .5	90 .0
SEE.....	54.5	1887.70	0.781	1 .014	Indeterminate	0 .0	169 .5*
AITKEN.	63.0	1887.0	0.76	1 .00	154 .7	24 .7	11 .3

* The angle of periastron, as the apparent and real orbits are identical.

The present elements, like the preceding ones, can only be considered as preliminary, and it will be many years before a satisfactory orbit can be computed, for the motion of the small star at present is very slow. A short ephemeris is:—

1901.50	323°.2	1''.38
1902.50	325 .0	1 .43
1903.50	326 .6	1 .47
1904.50	328 .1	1 .51
1905.50	329 .5	1 .55

October, 1900.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1901.

By Malcolm McNeill.

January.

The Earth is in perihelion at noon on January 2d, Pacific time.

Mercury passed greatest west elongation in December, and is too near the Sun when January begins to be easily seen. It rapidly approaches the Sun, passes superior conjunction on January 21st, and becomes an evening star, but does not recede far enough from the Sun to be seen with the naked eye before the end of the month.

Venus is still a morning star, but is gradually overtaking the Sun in its eastward motion, and the distance between the two is diminished from 31° to 23° during the month. The planet moves about 40° eastward from *Scorpio* through the southern extension of *Ophiuchus* to the eastern boundary of *Sagittarius*. It is in conjunction with *Uranus* on January 4th, passing 1° 10′ north, with *Jupiter* on January 15th, passing 0° 22′ north, and with *Saturn* on January 24th, passing 0° 20′ south. It then rises only $1^h\ 20^m$ before sunrise.

Mars is gradually approaching opposition, and is beginning to rise at a time suitable for observation before midnight. It moves about 1° eastward in the constellation *Leo* up to January 14th, and then begins to retrograde, moving about 2° westward before the end of the month. In retrograding it follows a path a little north of the one described while it was moving eastward. Its distance from the Earth diminishes from eighty-seven millions to sixty-eight millions of miles, and its brightness increases more than one half.

Jupiter, *Saturn*, and *Uranus* are all early-morning objects, and not one of them is well situated for observation. All three passed conjunction with the Sun in December. *Jupiter* rises long enough before sunrise to be easily seen; *Uranus* rises about an hour earlier than *Jupiter*, but cannot easily be made out on account of its faintness; *Saturn* is much nearer the Sun, and can probably not be seen with the naked eye until after the middle of the month.

Neptune is a little past opposition with the Sun, and is in good position for evening observation on the border of *Taurus* and *Gemini*, but it needs a telescope to bring it out.

FEBRUARY.

Mercury is an evening star throughout the month, and comes to greatest east elongation on the afternoon of February 19th, but the apparent distance of the planet from the Sun is much less than the average distance at greatest elongation, because the planet is in perihelion on the morning of the same day. It can probably be seen by the naked eye, when the weather conditions are favorable, for a week or two, but the conditions for visibility will be much more favorable during the following greatest east elongation, which is due in June.

Venus is still a morning star, but is even nearer the Sun than during January. By the end of the month it is about 14° west of the Sun, and it is also 7° south; so that the interval between the rising of the planet and sunrise is only about half an hour, and the planet will be hard to see.

Mars reaches the best position for observation it has given us since its last opposition, a little more than two years ago. It is in opposition with the Sun on the evening of February 21st. As compared with other oppositions, however, this is about the most unfavorable, since the planet comes to aphelion on February 24th, only three days from the time of opposition. Its distance from the earth will then be only a little less than sixty-three millions of miles, whereas during an August opposition the distance is nearly thirty millions of miles less. The brightness of the planet will be only about one fourth of its brightness at a favorable opposition. It will, however, be several times brighter than the first-magnitude star *Regulus*, which is near it. It is in the constellation *Leo*, and moves about 10° westward and southward during the month, and at the end is about 3° east and north of *Regulus*.

Jupiter, *Saturn*, and *Uranus* are still in the morning skies, but are farther away from the Sun, and rise nearly two hours earlier than during January. *Jupiter* and *Saturn* are both in *Sagittarius* and are moving eastward. *Jupiter* more than 5°, and *Saturn* about 3°; so that at the end of the month they are less than 7° apart. This distance will still further diminish until the end of April, when the planets begin their retrograde motion. *Uranus* is higher up than *Jupiter* and *Saturn*, a little more than an hour's motion ahead of *Jupiter* and at about the same declination.

Neptune is in about the same position between *Taurus* and *Gemini*.

JANUARY–FEBRUARY, 1901.

PHASES OF THE MOON, P. S. T.

Full Moon	Jan. 4,	4^h 13^m	P. M.
Last Quarter . . .	Jan. 12,	12 38	
New Moon . . .	Jan. 20,	6 36	A. M.
First Quarter . . .	Jan. 27,	1 52	
Full Moon	Feb. 3,	7 30	
Last Quarter . . .	Feb. 11,	10 12	
New Moon	Feb. 18,	6 45	P. M.
First Quarter . . .	Feb. 25,	10 38	A. M.

THE SUN.

1901.	R. A.	Declination.	Rises.	Transits.	Sets.
Jan. 1,	$18^h 45^m$	− 23° 2′	$7^h 27^m$ A.M.	12^h 4^m P. M.	$4^h 41^m$ P.M.
11,	19 29	− 21 52	7 27	12 8	4 49
21,	20 12	− 19 59	7 22	12 11	5 0
31,	20 54	− 17 29	7 15	12 14	5 13
Feb. 10,	21 34	− 14 29	7 4	12 14	5 24
20,	22 13	− 11 3	6 52	12 14	5 36
Mar. 2,	22 51	− 7 21	6 37	12 12	5 47

MERCURY.

Jan. 1,	17 53	− 24 4	6 40 A.M.	11 12 A.M.	3 44 P.M.
11,	19 2	− 24 15	7 7	11 40	4 13
21,	20 12	− 22 5	7 31	12 12 P.M.	4 53
31,	21 23	− 17 21	7 44	12 43	5 42
Feb. 10,	22 30	− 10 20	7 46	1 10	6 34
20,	23 18	− 3 0	7 20	1 10	7 0
Mar. 2,	23 21	− 0 25	6 43	12 42	6 41

VENUS.

Jan. 1,	16 40	− 20 55	5 13 A.M.	9 58 A.M.	2 43 P.M.
11,	17 33	− 22 28	5 43	10 12	2 51
21,	18 27	− 22 55	5 50	10 27	3 4
31,	19 21	− 22 12	6 1	10 41	3 21
Feb. 10,	20 14	− 20 22	6 7	10 55	3 43
20,	21 6	− 17 33	6 8	11 7	4 6
Mar. 2,	21 55	− 13 54	6 5	11 17	4 29

MARS.

Jan. 1,	10 58	+ 10 9	9 42 P.M.	4 17 A.M.	10 52 A.M.
11,	11 1	+ 10 9	9 6	3 41	10 16
21,	11 9	+ 10 37	8 25	3 1	9 37
31,	10 54	+ 11 33	7 36	2 16	8 56
Feb. 10,	10 43	+ 12 51	6 41	1 26	8 11
20,	10 29	+ 14 17	5 44	12 33	7 22
Mar. 2,	10 14	+ 15 35	4 39	11 33	6 27

JUPITER.

Jan. 1,	17 43	− 23 5	6 24 A.M.	11 1 A.M.	3 38 P.M.
Feb. 1,	18 12	− 23 9	4 51	9 28	2 5
Mar. 1,	18 34	− 22 59	3 23	8 0	12 37

SATURN.

Jan. 1,	18 34	− 22 37	7 13 A.M.	11 52 A.M.	4 31 P.M.
Feb. 1,	18 49	− 22 24	5 26	10 5	2 44
Mar. 1,	19 0	− 22 10	3 47	8 27	1 7

URANUS.

Jan. 1,	16 52	− 22 31	5 31 A.M.	10 10 A.M.	2 49 P.M.
Feb. 1,	16 59	− 22 42	3 37	8 15	12 53
Mar. 1,	17 2	− 22 47	1 51	6 29	11 7 A.M.

NEPTUNE.

Jan. 1,	5 49	+ 22 11	3 46 P.M.	11 6 P.M.	6 26 A.M.
Feb. 1,	5 46	+ 22 11	1 40	9 0	4 20
Mar. 1,	5 45	+ 22 11	11 49 A.M.	7 9	2 29

ECLIPSES OF *JUPITER'S* SATELLITES, P. S. T.

(Off left-hand limb as seen in an inverting telescope.)

II, D, Jan.	13,	$5^h\ 0^m$ A.M.	II, D, Feb.	7,	$1^h\ 59^m$ A.M.
I, R,	16,	2 52	I, D,	8,	3 1
III, D,	16,	6 23	II, D,	14,	4 33
I, D,	23,	4 46	I, D,	15,	4 55
I, D,	30,	6 39	III, D,	21,	2 12
			III, R,	21,	4 45
			I, D,	22,	6 49
			I, D,	24,	1 18
			I, D,	28,	6 10

"AN ATLAS OF REPRESENTATIVE STELLAR SPECTRA."[*]—A REVIEW.

By W. W. CAMPBELL.

This is the title of "PUBLICATIONS OF SIR WILLIAM HUGGINS'S OBSERVATORY, VOL. I.," by Sir WILLIAM HUGGINS, K. C. B., and Lady HUGGINS, issued in March, 1900. Outwardly, the volume is a masterpiece of the bookmaker's art. It is doubtful if any other astronomical book of this century is so truly an *édition de luxe*. In addition to thirteen half-sheet pages of celestial spectrograms, there are splendid photographic illustrations of the observatory and its instruments; and the charm of the book is greatly enhanced by some fifteen headpieces and initials exquisitely sketched by the pen of Lady HUGGINS. The pleasure of the reader is increased by these evidences that the beautiful in astronomy has not escaped the esthetic sense of the authors.

---

[*] Published by WM. WESLEY & SON, London. £1 5s net.

These external charms have their counterparts in the text. It is a record of pioneer work in stellar spectroscopy, written in sufficient detail to interest the technical astrophysicist, but in language so simple that the general reader can comprehend equally well.

Sir WILLIAM HUGGINS'S observatory, founded in London in 1856, contained at first a five-inch Dolland telescope, which was replaced by an eight-inch Clark in 1858. His work was mainly in the line of physical observations of the planets. KIRCHHOFF'S discovery of the significance of the Fraunhofer spectrum-lines in 1859 attracted HUGGINS'S attention to the possibility of applying these newly discovered principles to the study of the stars. Inviting Dr. MILLER, Professor of Chemistry in King's College, to join him in the work, these gentlemen constructed a small spectroscope and attached it to the eight-inch refractor; and their great work of laying the foundations of the spectroscopic astronomy began at once. "The observatory became a meeting-place where terrestrial chemistry was brought into direct touch with celestial chemistry. The characteristic light-rays from terrestrial hydrogen shone side by side with the corresponding radiations from starry hydrogen, or else fell upon the dark lines due to the absorption of hydrogen in *Sirius* or in *Vega*. Iron from our mines was matched, light for dark, with stellar iron from opposite parts of the celestial sphere. Sodium, which upon the Earth is always present with us, was found to be widely diffused through the celestial spaces.

"The time was, indeed, one of strained expectation and of scientific exaltation for the astronomer, almost without parallel; for nearly every observation revealed a new fact, and almost every night's work was red-lettered by some discovery."

The preliminary results obtained by HUGGINS and MILLER, showing that the chemistry of the solar system prevails wherever the spectroscope was pointed, were communicated to the Royal

Society in 1862. It is a remarkable fact that on the day their paper was read the Society learned that similar observations had been made by RUTHERFURD in New York. A little later, the spectra of the stars were also studied by SECCHI in Italy, and by VOGEL in Germany.

Perhaps the most interesting observation of all was that made by HUGGINS in August, 1864, on the planetary nebula in *Draco*. It is hardly possible for the younger members of our profession to realize the profound interest taken in the discussion of questions concerning the nebulæ. The increasing power and perfection of telescopes had enabled HERSCHEL and others to resolve one nebula after another into stars; and it was held by many that all nebulæ were probably clusters of stars, which the powerful telescopes of the future would resolve. HERSCHEL himself was of the opinion that the very extended nebulosities, at least, were composed of matter self-luminous, "more fit to produce a star by its condensation, than to depend on the star for its existence."

HUGGINS'S observation of the *Draco* nebula solved the problem. The spectrum was monochromatic. First, one bright line was visible; and later two others were detected. This nebula was "not an aggregation of stars, but a luminous gas." Of sixty nebulæ and clusters examined, about one third gave the bright-line spectrum, indicating their gaseous nature.

The first observations of the spectrum of a "new star" were made by HUGGINS and MILLER in May, 1866.

About this time HUGGINS recognized the possibility of measuring the motion of a star in the line of sight, by means of the displacement of its spectrum; and a spectroscope for this purpose was constructed. While the enormous difficulties of the subject were not overcome, yet his ideas were opening up a field whose limits cannot even now be discerned.

HUGGINS'S observations of a comet spectrum in 1868 led at once to the recognition of the important part played in comets by carbon; and his photograph of a comet spectrum in 1881 led to the detection of nitrogen radiations in these bodies.

His resources were greatly increased in 1870 by the loan, from the Royal Society, of a 15-inch Grubb refractor and an 18-inch speculum reflector.

It is interesting to note HUGGINS'S courage in trying new methods: stellar spectrograms were attempted in 1863 with wet-plates; but these plates were impracticable, and their use had to be given up. His photographic work began again in 1875–76, when rapid dry-plates were available. Many of the spectra on which he had worked visually were now studied photographically. His photographs have been taken largely with spectrographs provided with Iceland-spar prisms and quartz lenses. These materials transmit the radiations of short wave-lengths, and his spectra of the brighter stars extend far into the ultra-violet.

Sir WILLIAM HUGGINS'S chief interest has been in reference to the evolution of the stars; and his photographs are discussed almost entirely from this point of view. His earlier observations on the visual portions of the spectra led him to arrange the brighter stars as to their age, or state of development, about as follows: —

Sirius.— Vega.
. . . . . .
α *Aquilæ.*
Rigel.
α *Cygni.*
. . . . . .
. . . . .
Capella.—The Sun.
Arcturus.
Aldebaran.
Betelgeux.

His researches on the ultra-violet spectra of those stars confirm, in his opinion, the above order of arrangement. The discussion of this question is the chief technical interest of the volume. It is based on HELMHOLTZ'S law that the mutual gravitation of the previously widely separated portions of a star is sufficient to account for the high temperature generated in it; on LANE'S law that the temperature of a star will increase so long as the star is purely gaseous, after which the temperature will decrease; and on the generally accepted fact that as the temperature rises the maximum of the continuous spectrum shifts to the violet. HUGGINS'S observations have led him to the somewhat unexpected conclusion that the true continuous spectrum is relatively stronger in the ultra violet of the metallic or solar type stars, such as *Procyon* or *Capella*, than in the white stars, *Sirius* or *Vega*. HUGGINS'S photographs taken with spar and quartz optical trains are practically the only ones extant which bear strongly upon this important discovery. Confirmatory photographs, covering a large number of stars, are greatly to be desired. Granting HUGGINS'S result to be indeed a fact, his stellar classification follows with comparative ease and certainty.

The authors describe, further, a series of experiments on the behavior of the calcium spectrum under varying conditions, and the results furnish further confirmation of their system of classification.

The book is referred to on the title page as Volume I. The appearance of subsequent volumes will be anticipated with interest.

NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DETERMINATION OF THE SUN'S DISTANCE, FROM OBSERVATIONS OF *EROS*.

The tendency of the times toward thorough organization and co-operation in large enterprises is well illustrated in modern astronomy. Thirty years ago, a dozen leading observatories, by mutual agreement, divided the northern sky into zones in such a way that their meridian-circle observations would combine to form the excellent Astronomische Gesellschaft star-catalogue; and this great work is now nearing completion. The work of charting the sky by means of photography was similarly organized by the Astrographic Conference in Paris, some ten years ago.

About fifty of the principal observatories of the world are now co-operating in a great programme of observation for improving our knowledge of the distance between the Earth and Sun. Fully half the resources of the Lick Observatory have been devoted to this work for two months past, and the observations will continue one or two months longer.

The determination of the value of this astronomical unit of distance is one of the most famous problems in the science, and a great variety of methods has been used. Perhaps the best determination is that made by Sir DAVID GILL of the Cape of Good Hope, from heliometer observations of the nearer asteroids. The four hundred small planets (asteroids) discovered up to 1898 all move in orbits situated entirely outside the orbit of *Mars*. The observations of *Victoria*, *Iris*, and *Sappho*, which approach nearer to the Earth than any of the other members of the asteroid group, led to the result that the average distance from the Earth to the Sun is about 92,900,000 miles, The unavoidable errors to which all such observations are subject leave an uncertainty of some 150,000 miles in this value: it may be too large or too small by this amount.

---

* **Lick Astronomical Department of the University of California.**

The accuracy of results obtained in this manner depends upon the distance of the observed body from the Earth, and upon its definiteness as a point of observation. *Mars* possesses the advantage of being nearer the Earth than the asteroids, but this advantage is greatly outweighed by the fact that an asteroid-point can be observed much more accurately than a large planet-disk. GILL's splendid work left much to be desired, but there was no prospect that his value of the unit could be improved with instruments now available.

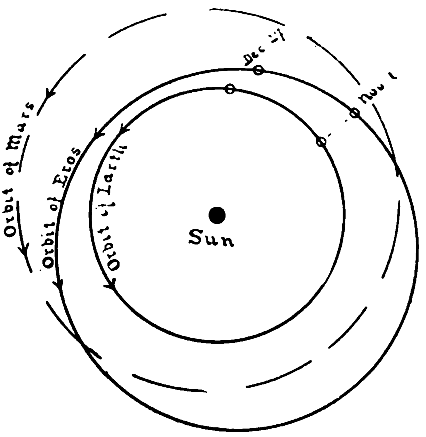


Fig. 1

An asteroid discovered by Dr. WITT in Berlin, in 1898, to which he gave the name *Eros*, is very remarkable in that its orbit lies partly within and partly without the orbit of *Mars*. It approaches the Earth more closely than any other member of our system, except the Moon. The forms and relative positions of the orbits of the Earth, *Eros*, and *Mars* are shown approximately by the accompanying diagram (Fig. 1). The orbits of *Mars* and *Eros* appear to intersect; but this is merely apparent, from the projection of the two on the plane of the paper. The plane of the orbit of *Eros* makes an angle of about eleven degrees with the plane of the orbit of *Mars* (and the Earth), and the two orbits are situated like two adjacent links of a chain without approaching each other very closely.

As soon as the orbit of this wonderfully-located asteroid was computed and published, astronomers realized its possibilities for improving our knowledge of the Sun's distance. As stated above, an asteroid's value for this purpose depends upon its closeness to the Earth. The distance of *Eros* at this opposition will have a minimum value of 27,000,000 miles. Unfortunately, the more favorable opposition of 1896, when the distance diminished to 15,000,000 miles, was not available, as the planet remained undiscovered; and an equally good opposition will not occur again for a quarter of a century.

In outline, this method of measuring the Sun's distance is exceedingly simple; but in detail it is exceedingly complex and technical. The nature of the problem may be explained from Fig. 2.

If the Earth is at E and the asteroid at A, an observer on the Earth's surface at P will see the asteroid projected on the sky at P′, whereas an observer at L will see it at L′. If the distance PL is known, as it is, and the angle PAL is obtained from the observations, the data for solving the triangle PLA are at hand, and the distance EA may be obtained by simple computation. As a second step in the solution, the orbit of *Eros* will be determined very accurately, basing the determination upon Newton's law of gravitation. It will then be a simple matter to compute the ratio of the Earth's distances from the Sun (ES) and the asteroid (EA). The distance EA having already been determined in miles, the desired distance ES will follow.

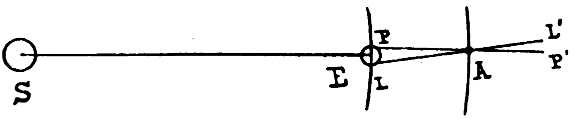


Fig 2

If two observatories on opposite sides of the Earth secure observations simultaneously, say at P (Pulkowa, in Russia) and at L (Mt. Hamilton), the desired data are theoretically complete; but practically they are insufficient. There are unavoidable errors in the measurement of the very small angle PAL, and in the assumed positions of the two observatories, which will be materially reduced by having observations made at a large number of stations. The direct distance between the Pulkowa and Lick Observatories is about 5,000 miles. This is a base-line from which to measure a distance of 27,000,000 miles, and thence the three-and-one-half-fold greater distance to the Sun. The form and the dimensions of the Earth thus enter directly into the problem. An error of a quarter of a mile in the assumed length of the base-line leads to a large error in the final result.

Instead of simultaneous observations made in the morning in Russia and in the evening in America, the angle PAL can be determined by evening and morning measures secured at one station.

The July conference of astronomers at the Paris Exposition afforded an opportunity for a hurried formation of co-operative plans to secure the observations needed. It may be said that every one of the contributing observatories is devoting to this problem all of its resources which in any way promise to improve the results. The measures are most advantageously made in November and December; and perhaps a hundred observers are giving their time to this work. The reductions will require one or two years' labor, and the value of the Sun's distance, resulting from a combination of all the work of all the observatories will probably not be available for two or three years.

The Lick Observatory is contributing as follows:—

Astronomer R. H. TUCKER, assisted by Mr. CRAWFORD, is securing two meridian-circle observations of each of 700 stars, to determine their positions with the utmost accuracy. These positions, furnished by perhaps a dozen or more observers, will form the triangulation system, or groundwork, upon which the whole structure of the determination will be based.

Astronomer W. J. HUSSEY and Assistant Astronomer R. G. AITKEN, with the assistance of Mr. WRIGHT and Dr. REESE, are using the great telescope five or six nights per week, weather permitting, to measure the evening and morning positions of *Eros* with reference to the fixed stars in the asteroid's vicinity. The positions of these reference-stars will be secured by means of photographs of the regions taken with eight or ten telescopes, mostly in Europe.

Assistant Astronomer C. D. PERRINE, assisted by Mr. PALMER, is employing the Crossley reflector every clear night to obtain photographs of *Eros* and its surrounding stars, to furnish the planet's accurate position in the evening, in the morning, and on the meridian. The measurement of these plates will be a heavy task. Fortunately, Professor REES, Director of the Columbia University Observatory, has volunteered to measure them. Columbia University is the only institution in this country which has had experience in measuring such plates, though many foreign observatories have long been doing similar work.

The planet *Eros* is now of about the 9.3 magnitude. It is easily visible in a three-inch telescope. W. W. CAMPBELL.

LICK OBSERVATORY, November 24, 1900.

Observations of the Binary Stars δ *Equulei* (=OΣ535,) and κ *Pegasi* (= β 989,) in 1900.

In carrying out my programme of observing the more interesting and difficult binary stars annually, I turned the 36 inch telescope upon κ *Pegasi* on the night of July 22, 1900, and secured a measure without particular difficulty, though the distance between the two components was only 0″.17. Turning next to δ *Equulei*, which is a very similar pair in point of magnitude, I was unable to make a measure. This was a great surprise to me; for a year ago it was much easier to measure than κ *Pegasi*, and my recollection of the generally accepted orbit did not lead me to expect so rapid a diminution in the distance.

On the night of August 10th, with rather poorer conditions, I again failed on δ *Equulei*, and turning directly afterward to κ *Pegasi* secured a satisfactory measure. On the following night, Saturday, August 11th, the seeing was excellent, and I was able to detect a slight, but certainly real elongation of δ *Equulei*, regarding which my observing note says "the distance (between the two components) is not greater than the thickness of the micrometer-wire,"—i. e., less than one tenth of a second of arc. Perhaps the best estimate of the observing conditions on this night may be formed from the fact that in little over five hours I secured measures of eighteen pairs of double stars, ten of which had distances of less than 0″.25 and only three, distances greater than 0″.50. Having measured a pair with a distance of 0″.15 shortly before turning to δ *Equulei*, and κ *Pegasi* (distance 0″.17) immediately afterward, I am confident that the observing note just quoted states the distance correctly.

After failing again, on September 8th, to see any elongation in this star, though the seeing was good enough to make possible the measures of seven other pairs at an average distance of 0″.30, I called the attention of Professor Hussey, who is specially interested in the Otto Struve double stars at present, to δ *Equulei*. For it was obvious that the existing orbits needed radical modifications to account for so small a separation between the two components at the present time. According to Dr. See's revised orbit, the latest one published, the distance has been diminishing during the past two years, but at the date, 1900.85 (about November 7th) it should still be 0″.28, an easily measurable quantity with the 36-inch refractor on any good night.

In the past two months I have examined δ *Equulei* on four nights when the seeing was good enough to measure very close stars. Three times I suspected elongation; once I failed completely. Settings were made on the suspected elongations, but were marked "uncertain," — particularly the last two — and the resulting angles differed so greatly that they seemed more than ever doubtful.

The short period elements, however, which Professor HUSSEY has recently completed (see p. 215 of this number), without reference to any of these observations, except the one on August 11th, indicate that in all probability the elongations noted were real; for, according to these elements, the distance during the past few months has been considerably less than 0″.10, and therefore a residual in angle of even 28° means a displacement of the micrometer-wire of only one third of its own thickness.

In view of the very interesting result obtained by Professor HUSSEY in his study of the orbit of this star, it has seemed desirable to make this detailed record of my observations. The tabular statement is as follows : —

Date.	Position-Angle.	Distance.	Eye-piece.	Seeing.
1900 557	........Failed to measure		1900	3
.609	........Failed to measure		1500	3
.612	........137°.8 (317°.8)...	<0″.10	2600	4+
.688	........No elongation seen		1900	3
.746	Elongat'n suspect'd in 107°.2	<0″.10	2600	4
.787	Two micrometer settings gave an angle of 95°.3. My observing note says: "Settings quite uncertain, but star certainly elongated in general preceding-following direction."		1900	3
.836	....No elongation seen		1900	3
.858	One "very uncertain" setting gives an angle of 84°		1900	3

The measures of κ *Pegasi* are as follows : —

1900.557	272°.8	0″.17	1500	3
.576	267°.2	0″.17	1500	3
.609	266°.1	0″.18	1500	3
.612	265°.0	0″.17	1900	4+
1900.59	267°.8	0″.17		

According to BURNHAM'S elements for this pair, the position in 1900.59 was 263°.5 and 0".16, leaving residuals for the above observations of (O − C) +4°.3 and +0".01. As the smaller star has moved over an arc of 220° since these elements were computed, such an agreement between prediction and observation indicates that BURNHAM'S orbit is very exact.

November 16, 1900. R. G. AITKEN.

LEONIDS IN 1900.

About a week previous to November 15th, a number of meteors were seen which appeared to come from the *Leonid* radiant. All were seen well toward the western horizon, and had the characteristics of the *Leonids*. No especial watch was kept for them then. On the morning of Thursday, November 15th, meteors were counted from $15^h\ 15^m$ to $15^h\ 55^m$. During this time nine were seen, of which eight were *Leonids*. None were of unusual brilliancy. Attention was directed more to the western sky on account of greater cloudiness to the east. Clouds at all times covered considerable portions of the sky so that probably not more than half as many meteors were observed as would have been visible in an entirely clear sky. A severe storm (still in progress) has prevented further observations.

MT. HAMILTON, November 21, 1900. C. D. P.

OBSERVATIONS OF *LEONID* METEORS.

Six meteors coming approximately from the position of the Sickle in *Leonis* were observed this (Thursday) morning between half-past three and four o'clock P. S. T. The sky was cloudy throughout the morning, during the interval of observation from three tenths to five tenths being covered. Most of the meteors were faint, and were observed in the western sky, this being the part most free from clouds. No other meteors were seen.

November 15, 1900. W. H. W.

OBSERVATIONS OF *LEONIDS* ON THE MORNING OF NOVEMBER 15TH.

In making these observations no attempt was made to record the separate paths of the meteors, all meteors emanating from the constellation *Leo* being counted together. The observations extended from 2:55 to 4:30 A. M., being taken during alternate intervals of five minutes throughout this time. Ten *Leonids* in all were counted. During all this time there were light clouds in the neighborhood of *Leo*, and for about twenty minutes clouds and fog were so thick that only the brighter stars in the constellation were visible. After 4:30 the clouds thickened so much that the meteors were no longer watched for. The part of the sky covered by the observer included about fifty degrees on all sides of the radiant. H. M. R.

GENERAL NOTES.

Members and friends of the Society are invited to aid the Committee on Publication in carrying out the work of this department. Communications of general interest will be gladly received, and may be sent to SIDNEY D. TOWNLEY, 2023 Bancroft Way, Berkeley, California.

Dr. HENRY S. PRITCHETT, for some years Professor of Astronomy in Washington University, St. Louis, and recently Superintendent of the United States Coast and Geodetic Survey, was inaugurated President of the Massachusetts Institute of Technology on October 24th.

The degree of Doctor of Science has been given by Cambridge University to Professor S. P. LANGLEY, Director of the Smithsonian Institution.

Dr. HERMAN S. DAVIS, recently expert computer of the United States Coast and Geodetic Survey, has been appointed observer at the International Latitude Observatory at Gaithersburg, Maryland, one of the six stations established by the Central Bureau der Internationalen Erdmessung for an investigation of variations of latitude.—*Science*, November 9, 1900.

The will of Professor PIAZZI SMYTH makes provision for the publication of his spectroscopic manuscripts, and also for the assistance or promotion every ten or twenty years of an expedition for the study of some particular branch of astronomical spectroscopy at mountain elevations of not less than 6,000 feet.

Nature for October 25th contains an interesting article under the title, "Recent and Proposed Geodetic Measurements." From it we learn that the French propose to remeasure the Peruvian arc measured by BOUGNER in 1735–45. A preliminary survey of the region has been made, and it has been decided to extend the arc at both ends so that it will cover six degrees of latitude, about twice the extent of the former measurement. The arc will cross the equator extending from the neighborhood of Sullana in Peru to Pasto in Columbia. The country is far from smooth, and the task will be a difficult one. "Three bases of about eight or nine kilometers in length will be measured, one approximately central and two of verification at the north and south ends respectively. The difference of level between the central base and the sea at Guayaquil, where tide-gauges will be erected, will be determined with the greatest nicety. Throughout the arc fifty-two stations will be selected for observation, of which three will be fundamental, and the longitudes be determined by telegraph. Magnetic observations will be carried on as a matter of course, and in a country marked by so many mountain masses special care will be taken to determine their extent and density, with the view of eliminating the effect of local attraction." The work of this survey will be commenced next spring.

The Russian and Swedish governments are carrying out the measurement of an arc in the extreme north, in Spitzbergen, between latitudes seventy-seven and eighty-one degrees. Two base lines will be measured and fifty triangulation stations occupied. The work is already well under way.

A third arc is now being measured in South Africa, and if the director of the work, Sir DAVID GILL, Her Majesty's Astronomer at the Cape of Good Hope, is able to carry out his plans, this will dwarf into insignificance anything heretofore done in the way of measuring an arc of a meridian. He proposes to extend the measurements from the Cape of Good Hope to the mouth of the Nile, and thence across the Mediterranean Sea by means of the islands of Greece, and there to connect with the European systems, making in all an arc 105° in extent. It is to be hoped that the plan can be successfully carried out, but the difficulties are many. A start upon the work has already been made, but measurements are temporarily at a standstill on account of the war with the Boers.

The November number of *Popular Astronomy* contains an interesting account of the opening of the Whitin Observatory of Wellesley College. The building, of white marble, was built and equipped by one of the trustees of the College, Mrs. JOHN C. WHITIN. "The initial equipment consists of a 12-inch Clark equatorial refractor, a 3-inch transit, a sidereal clock, chronograph and a 6-foot-focus Rowland concave-grating spectroscope with heliostat. The telescope is furnished with spectroscope for solar work, polarizing photometer, micrometer, and small star spectroscope, all with electric illumination. Other minor instruments are already purchased, and it is intended to provide less costly apparatus in duplicate for the elementary practice of laboratory divisions."

Two addresses were given on the occasion, one by Professor EDWARD C. PICKERING, of Harvard, on "The New Planet *Eros*," the other by Professor DAVID P. TODD, of Amherst, on "Laboratory Work in Astronomy."

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE ROOMS OF THE SOCIETY, NOVEMBER 24, 1900, AT 7:30 P. M.

Mr. BURCKHALTER presided. A quorum was present. The minutes of the last meeting were approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED NOVEMBER 24, 1900.

Mr. A. D. AUSTIN	Carlton Terrace, Christchurch, New Zealand.
Mr. PAUL M BENEDICT	Care of Thos. H. Pease & Son, 102 Church St, New Haven, Conn.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE CALIFORNIA ACADEMY OF SCIENCES, NOVEMBER 24, 1900, AT 8 O'CLOCK P. M.

Mr. PIERSON presided. The minutes of the last meeting were approved.

The following papers were presented:—

1. On the Progress made in the Last Decade in Determination of Stellar Motions in the Line of Sight, by H. C. VOGEL. (Reprinted from *Astrophysical Journal*)
2. Planetary Phenomena for January and February, 1901, by MALCOLM MCNEILL.
3. The Orbit of *99 Herculis*, by R. G. AITKEN.

Mr. PIERSON opened the meeting with an account of the life of Professor KEELER, late President of the Society, and read the resolutions adopted expressing the sorrow felt by the members at his untimely death.

He then introduced the lecturer of the evening, explaining the importance to science of the new method of photographing the Corona, and read a number of letters from the most eminent astronomers, expressing in the highest terms their gratification at the successful results obtained.

Mr. BURCKHALTER gave an account of his expedition to Siloam, illustrated by lantern slides of the eclipse station and of the photographs of the Corona, and explained, by means of drawings and models of his apparatus, the method by which the exposure of the plates is controlled.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. JAMES E. KEELER*	*President*
Mr. CHARLES BURCKHALTER	*First Vice-President*
Miss R. O'HALLORAN,	*Second Vice-President*
Mr. S. D. TOWNLEY	*Third Vice-President*
Mr. C. D. PERRINE Mr. F. R. ZIEL	*Secretaries*
Mr. F. R. ZIEL	*Treasurer*

Board of Directors—Messrs. BURCKHALTER, CAMPBELL, DOLBEER, HILL, KEELER,* MOLERA, Miss O'HALLORAN, Messrs. PERRINE, PIERSON, TOWNLEY, ZIEL.

Finance Committee—Messrs. PIERSON, BURCKHALTER, HILL.

Committee on Publication—Messrs. AITKEN, TOWNLEY, VON GELDERN.

Library Committee—Mr. TOWNLEY, Miss O'HALLORAN, Miss HOBE.

Committee on the Comet-Medal—Messrs. KEELER* (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FRANCISCO RODRIGUEZ REY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

---

* Deceased.

INDEX TO VOLUME XII.

PAGE

AITKEN, R. G., Double Star Notes, 31; The Orbit of T *Cgyni*, 103; New Double Stars, 127; *Venus* by Daylight, 198; Note on *Capella* as a Double Star, 202; A New Planetary Nebula, 203; The Orbit of 99 *Herculis*, 240; Observations of the Binary Stars δ *Equulei* and κ *Pegasi* in 1900 255

Asteroids: See Minor Planets.

Astronomical and Astrophysical Society of America, Second Annual Meeting of 208

Astronomical Instruments, Review of Dr. AMBRONN's Handbook of, by J. E. KEELER 117

Astronomical Observations in 1899, by TORVALD KÖHL 56

Astronomical Society of the Pacific, Address of Retiring President of, 49; Annual Report of Treasurer of, 85; Award of Bruce Medal of, 82; Corresponding Institutions of, 10; Exchanges of, 11; Members of, 1; Minutes of Meetings of, 47, 84, 261; Minutes of Meetings of Directors of, 47, 82, 83, 87, 212, 261; Officers of, 48, 88, 137, 214, 262; Report of Comet-Medal Committee of 84

Astronomical Telegrams 76, 131, 205

Astronomy in America, The Development of 109

"Atlas of Representative Stellar Spectra," A Review, by W. W. CAMPBELL 246

AUWERS, ARTHUR, Portrait of . . . . Frontispiece

BAYLDON, FRANCIS J., Notes on the Zodiacal Light, 13; Observations of the Zodiacal Light from January, 1899, to July, 1900 184

Binary Stars: See Double Stars.

Book Notices 79, 133, 246

BURCKHALTER, CHAS., The Chabot Observatory-Dolbeer Eclipse Expedition, May 28, 1900, Programme of, 65; A Popular Account of 169

CAMPBELL, W. W., Note on the Spectrum of Comet *a*, 1899, 35; The Spectroscopic Binary, β *Herculis*, 39; JAMES EDWARD KEELER (Obituary), 139; The Crocker Expedition to Observe the Total Solar Eclipse of May 28, 1900 (with C. D. PERRINE), 175; The Triple Star, κ *Pegasi*, 202; Honor for, 204; HUGGINS's "An Atlas of Representative Stellar Spectra" (Review of), 246; Determination of the Sun's Distance from Observations of *Eros* . . 251

Capella:—
  As a Double Star, Note on, by R. G. AITKEN 202
  Visual Examination of, by W. J. HUSSEY 201

CODDINGTON, E. F., Rediscovery of Minor Planet (415), 36; New Minor Planet, 1899, EX, 39; Resignation of, as Fellow in Astronomy at the Lick Observatory 205

Comets:—
  Comet 1894 IV, SEARES's Definitive Elements of 43
  Comet 1896 V, Elliptic Elements of, by W. J. HUSSEY 200
  Comet *a*, 1899, Note on the Spectrum of, by W. W. CAMPBELL . 35

Comets:—
  Comet *a*, 1900, Elements of, by C. D. Perrine 75
  Comet *b*, 1900, Elements of, by C. D. Perrine, 204; Note on, by R. T. Crawford 204
  Comets of 1899, The, by C. D. Perrine 34
Crawford, R. T., Note on Comet *b*, 1900 204
Crossley Reflector of the Lick Observatory, The:—
  A Description of, by J. E. Keeler 146
  Discovery of a New Asteroid with 126
  Use of, for Photographic Measurements of Position 73
Description of Professor Keeler's Meridian-Circle 167
Development of Astronomy in America, The 109
Double Star Astronomy, Notes on the Progress of, by W. J. Hussey 91
Double Star Notes, by R. G. Aitken 31
Double Stars:—
  The Binary OΣ 341, by W. J. Hussey 38
  Capella, Note on, by R. G. Aitken, 202; Visual Examination of, by W. J. Hussey 201
  Discovery of Three Hundred, by W. J. Hussey 199
  Measures of Two Probably New, by C. D. Perrine 129
  New, by R. G. Aitken 127
  Observations of δ *Equulei*, and κ *Pegasi* in 1900, by R. G Aitken 255
  Orbit of τ *Cygni*, by R. G. Aitken 103
  Orbit of 99 *Herculis*, by R. G. Aitken 240
  The Spectroscopic Binary, β *Herculis*, by W. W. Campbell 39
  Trial Elements of the Binary Star, δ *Equulei*, by W. J. Hussey 215
  The Triple Star, κ *Pegasi*, by W. W. Campbell 202
Earthquake, The Mexican, of January 19, observed at the Lick Observatory 37
Eclipse Expedition:—
  The Chabot Observatory-Dolbeer, by Chas. Burckhalter, 64; A Popular Account of the Chabot Observatory-Dolbeer, by Chas. Burckhalter 169
  The Crocker-Lick Observatory, by J. E. Keeler, 74; Preliminary Account of Results of, by J. E. Keeler, 130; A General Account of, by W. W. Campbell and C. D. Perrine 175
Eclipse of the Sun, May 28, 1900, Brief Notes on the Results of Observations of 130, 135, 209
Gill, David, Award of Bruce Medal to 49, 82
Holden, E. S., Visual Observations of the Moon and Planets at Harvard College Observatory, (Review of) 61
Hussey, W. J., The Binary Star OΣ 341, 38; Notes on the Progress of Double-Star Astronomy, 91; Discovery of Three Hundred Double Stars, 199; Elliptic Elements of Comet 1896 V, 200; Visual Examination of *Capella*, 201; Trial Elements of the Binary Star δ *Equulei* (= OΣ 535) 215
Keeler, James E., The Mexican Earthquake of January 19, (1900,) Observed at the Lick Observatory, 37; Use of the Crossley Reflector for Photographic Measurements of Position, 73; The

Crocker-Lick Observatory Eclipse Expedition, 74; Photograph of the Trifid Nebula in *Sagittarius*, 89; Review of Dr. Ambronn's "Handbuch der Astronomischen Instrumenten-Kunde," 117; Discovery of a New Asteroid, 1899 FD, with the Crossley Reflector, 126; A Remarkable Meteor Train, 128; Preliminary Account of Results Obtained by the Crocker Eclipse Expedition of the Lick Observatory, 130; Obituary of, with Portrait, 139; The Crossley Reflector of the Lick Observatory 146; Description of a Meridian-Circle built by . . . 167

Köhl, Torvald, Astronomical Observations in 1899 . . . 56

Leonids: See Meteors.

Lick Observatory, Appointment of W. W. Campbell as Acting Director of, 206; Appointment of H. M. Reese as Fellow at, 206; Resignation of E. F. Coddington as Fellow at, 205; Volume IV of the *Publications* of the . . . 129

McNeill, Malcolm, Planetary Phenomena 26, 68, 121, 190, 243

Meteor, A Brilliant . . . 132

Meteor Train, A Remarkable . . . 128

Meteors:—

The *Leonids* in 1900, Note on, by C. D. Perrine, 257; by H. M. Reese, 257; by W. H. Wright, 257; Observations of, by Torvald Köhl, 58; by B. S. Mayhew . . . 42

Minor Planet, Discovery of a New (1899 EX), by E. F. Coddington, 39; Discovery of a New (1899 FD), with the Crossley Reflector, 126; Rediscovery of (415), by E. F. Coddington . . . 36

Nebula, A New Planetary, by R. G. Aitken, 203; Photograph of the Trifid, by J. E. Keeler . . . 89

Newcomb, Simon, Portrait of . . . Frontispiece

Observatories in California, Notes on the Work of . . . 44

Pardee, G. C., Address of the Retiring President of the Astronomical Society of the Pacific . . . 49

Perrine, C. D., The Comets of 1899, 34; Elements of Comet *a*, 1900, 75; Measures of Two Double Stars, Probably New, 129; The Crocker Expedition to Observe the Total Solar Eclipse of May 28, 1900 (with W. W. Campbell), 175; Elements of Comet *b*, 1900, 204; The *Leonids* in 1900 . . . 257

Planetary Phenomena, by M. McNeill . . . 26, 68, 121, 190, 243

Progress Made in the Last Decade in the Determination of Stellar Motions in the Line of Sight, by H. C. Vogel . . . 223

Publications of the Lick Observatory, Volume IV . . . 129

Reese, H. M., The *Leonids* in 1900 . . . 257

"Representative Stellar Spectra, An Atlas of," by Sir William and Lady Huggins, A Review, by W. W. Campbell . . . 246

Spectroscopic Binaries:—

β Herculis, by W. W. Campbell . . . 39

The Triple Star *κ Pegasi*, by W. W. Campbell . . . 202

Spectrum of Comet *a*, 1899 . . . 35

Stellar Motions in the Line of Sight, On the Progress Made in the Last Decade in the Determination of, by H. C. Vogel . . . 223

Sun's Distance from Observations of *Eros*, Determination of the, by W. W. CAMPBELL 251
Trifid Nebula, Phetograph of the, by J. E. KEELER 89
Variable Stars, Observations of, by TORVALD KÖHL 56
Venus by Daylight, by R. G. AITKEN 198
VOGEL, H. C., On the Progress Made in the Last Decade in the Determination of Stellar Motions in the Line of Sight 223
WRIGHT, W. H., Observations of *Leonid* Meteors 257
Zodiacal Light, Observations of, by F. J. BAYLDON 13, 184

Physics

520.6
A859
v.12
1900

DATE DUE			

STANFORD UNIVERSITY LIBRARIES
STANFORD, CALIFORNIA 94305-6004